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*A. J. Davis*  
ELEMENTS

OF

# CHEMISTRY.

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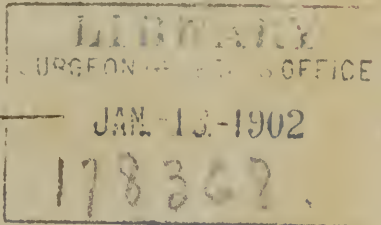
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TRANSLATED FROM THE FRENCH.

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THREE VOLUMES IN ONE.



PHILADELPHIA,

PRINTED BY LANG & USTICK,

For S. Ives, M. Carey, J. Cruikshank, H. & P. Rice, T. Dolson, R. Campbell, & J. Conrad.

M.DCC.XCVI.

THESE THINGS BEING CONSIDERED  
IT IS THE OPINION OF THE BOARD  
THAT IT IS ADVISABLE TO  
RECOMMEND TO THE  
COMMISSIONERS OF THE  
LAND OFFICE THAT THEY  
SHOULD BE AUTHORIZED TO  
CONVEY TO THE  
SAYED COLLEGE THE  
LANDS AND TENEMENTS  
WHICH ARE NOW  
IN POSSESSION OF  
THE SAYED COLLEGE  
AND TO GRANT TO  
THE SAYED COLLEGE  
A SUM OF MONEY  
FOR THE PURCHASE  
OF A NEW BUILDING  
FOR THE SAYED COLLEGE  
AND TO GRANT TO  
THE SAYED COLLEGE  
A SUM OF MONEY  
FOR THE PURCHASE  
OF A NEW BUILDING  
FOR THE SAYED COLLEGE

IN WITNESS WHEREOF

*THE* great experience of M. Chaptal, his unaffected candor, and the perspicuity which is seen in every part of the following treatise, cannot but render it extensively useful. I have been particularly careful not to diminish this last merit, by deviating in any respect from that scrupulous attention to accuracy which is indispensably required to give authority to the translation of a work of science.

London, April 1791.

W. NICHOLSON.



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## *Advertisement of the Author.*

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AGRICULTURE is no doubt the basis of public welfare, because it alone supplies all the wants which nature has connected with our existence. But the arts and commerce form the glory, the ornament, and the riches of every polished nation; since our refinement, and mutual dependence on each other, have created a new set of wants which require to be supplied. The cultivation of the arts is therefore become almost as necessary as that of the ground; and the true means of securing these two foundations of the reputation and prosperity of a state, consist in encouraging the Science of Chemistry, which discovers their principles. If this truth were not universally acknowledged, I might on the present occasion give an account of the success with which my labours have been attended in this province\*. I might even call upon the public voice; and it would declare that, since the establishment of lectures on chemistry, between three and four hundred persons have every year derived advantage from instructions in this science. It is well known that our ancient schools of medicine and surgery, whose success and splendour are connected with the general interest of this province, are more flourishing and more numerous since that period. And with the same confidence I might appeal to the Public, that our manufactures are daily increasing in perfection; that several new kinds of industry have been introduced into Languedoc; that, in a regular succession, abuses have been reformed in the manufactories, while the processes of the arts have been simplified; that the number of coal-mines actually wrought is increased; and that, upon my principles, and in consequence of my

C

\* Languedoc.

care and attention, manufactories of alum, of oil of vitriol, of copperas, of brown red, of artificial pozzolana, of ceruse, of white lead, and others, have been established in several parts of the province.

Chemistry is therefore essentially connected with the reputation and prosperity of a state; and at this peculiar instant, when the minds of men are universally busied in securing the public welfare, every citizen is accountable to his country for all the good which his peculiar situation permits him to do. Every one ought to hasten, and present to society the tribute of those talents which heaven has bestowed on him; and there is no one who is not able to bring some materials, and deposit them at the foot of the superb edifice which the virtuous administrators are raising for the welfare of the whole. It is with these views that I have presumed to offer to my countrymen the work which I at present publish; and I entreat them to exercise their severity upon the intention of the author only, but to reserve all their indulgence to the work.

I publish these Elements of Chemistry with the greater confidence, because I have had opportunities myself of observing the numerous applications of the principles which constitute its basis to the phenomena of nature and art. The immense establishment of chemical products which I have formed at Montpellier, has allowed me to pursue the development of this doctrine, and to observe its agreement with all the facts which the various operations present to us. It is this doctrine alone which has led me to simplify most of the processes, to bring some of them to perfection, and to rectify all my ideas. It is therefore with the most intimate confidence that I propose it. I find no difficulty in making a public acknowledgment that I have for some time taught a different doctrine from that which I at present offer. I then believed it to be true and solid; but I did not on that account cease to consult nature. I have constantly entered into this research with a mind eager for improvement. Natural truths were capable of fixing themselves with all their purity in my mind, because I

had banished prejudice; and insensibly I found myself drawn by the force of facts to the doctrine I now teach. Let other principles impress the same conviction on my mind; let the same number of phenomena and facts exhibit themselves in their favour; the same number of happy applications to the operations of nature and of art; let them appear to my mind with all the sacred characters of truth; and I will publish them with the same zeal, and with the same interest. I condemn equally the man who, attached to the ancient notions, respects them so much as to reject without mature examination every thing which appears to oppose them; and him who embraces with enthusiasm, and almost without reflection, the principles of any new doctrine. Both are worthy of compassion if they grow old in their prejudices; and both are worthy of blame if they perpetuate them.

I have been careful to banish all discussions from my work. That spirit of party which but too often causes a division between persons who are pursuing the same objects, that tone of bitterness which predominates in certain disputes, that want of candour which is insensibly produced by the movements of self-love, have but too long retarded the progress of our knowledge. The love of truth is the only passion which a philosopher ought to indulge. The same object, the same interest, tend to unite chemists. Let the same spirit inspire them, and direct all their labours. Then we shall soon behold chemistry advancing in a rapid progress; and its cultivators will be honoured with the suffrage and the gratitude of their countrymen,

I have endeavoured in this work to explain my ideas with clearness, precision, and method. I know by experience that the success of any work, and its various degrees of utility, often depend on the form under which the doctrine which it contains is displayed; and it has accordingly been my intention to spare no pains in exhibiting the truths which form the basis of this work in all the characters they are justly entitled to.



In composing these Elements of Chemistry, I have availed myself with advantage of all the facts which I have found in the works of the celebrated chemists who adorn this age. I have even made no scruple to follow their method in drawing up certain articles; and have transferred into my own work, almost without alteration, those facts which I have elsewhere found described with a greater degree of precision and perspicuity than I might have been capable of bestowing on them. This proceeding, in my opinion, renders homage to authors instead of robbing them. If such a proceeding might justify reclamations, Messrs. Lavoisier, De Morveau, Berthollet, De Fourcroy, Sage, Kirwan, &c. might easily declare against me.

I was well aware that the pretension of knowing, discussing and methodically distributing the whole of our present science of chemistry, was an enterprise beyond my ability. This science has made so great a progress, and its applications are so multiplied, that it is impossible to attend to the whole with the same care: and it appears to me that the writer of an elementary work ought at present to attend principally to the development of general principles, and content himself in pointing out the consequences, and their applications. In this way of proceeding we shall follow the method which has long been practised in the study of the mathematics; the principles of which, nearly insulated, and separated from all application, form the first study of him who means to acquire them.

To obtain a thorough acquaintance with all the knowledge which has been acquired in chemistry until our time, the chemical part of the *Encyclopédie Méthodique* may be consulted. In this work, the celebrated author gives the most interesting account of the progress of the science. Here it is that he discusses the several opinions with that candour and energy which become the man of letters whose mind is directed to truth only. Here it is that he has made a precious deposit of all the knowledge yet acquired, in order to present to us in the same point of view all

which has been done, and all which remains to be done : and here, in a word, it is that Mr. De Morveau has rendered the most striking homage to the truth of the doctrine we now teach ; because, after having combated some of its principles in the first volume, he has had the courage to recant the moment the facts seen in a better point of view, and repeated experiments, had sufficiently enlightened him. This great example of courage and candour is doubtless honourable to the learned man who gives it ; but it cannot fail to add still more to the confidence which may be placed in the doctrine which is its object.

The development of the principles upon which the New Nomenclature is established, may be found in the Elementary Treatise of Chemistry of Mr. Lavoisier ; and I refer likewise to this excellent work for the figure and explanation of all the apparatus I shall have occasion to speak of. I take this step the more earnestly, because, by associating my own productions to those of this celebrated chemist, I entertain the hope of securing their success, and can deliver them into the hands of the public with the greater confidence.

THE HISTORY OF THE

REIGN OF KING CHARLES THE FIRST

IN WHICH ARE CONTAINED THE  
MOST IMPORTANT AND INTERESTING  
PARTS OF HIS REIGN, FROM THE  
BEGINNING OF HIS REIGN, TO THE  
END OF HIS REIGN, IN THE  
YEAR OF HIS AGE SIXTY-ONE  
AND SEVEN, IN THE YEAR OF  
OUR LORD ONE THOUSAND SIX  
HUNDRED AND FIFTY-THREE  
BY JOHN BURNET, BISHOP OF  
SALISBURY, AND OF THE  
UNIVERSITY OF OXFORD  
IN TWO VOLUMES  
THE FIRST



## *Preliminary Discourse.*

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**I**T appears that the ancient nations possessed some notions of chemistry. The art of working metals, which dates from the most remote antiquity; the lustre which the Phœnicians gave to certain colours; the luxury of Tyre: the numerous manufactures which that opulent city included within its walls—all announce a degree of perfection in the arts, and suppose a considerable extent and variety of chemical knowledge. But the principles of this science were not then united into a body of doctrine; they were concentrated in the workshops of the manufactures, where they had their origin: and observations alone, transmitted from one operator to another, enlightened and conducted the steps of the artists. Such, no doubt, has been the origin of all the sciences. At first they presented unconnected facts; truths were confounded with error; time and genius alone could clear up the confusion; and the progress of information is always the fruit of slow and painful experiment. It is difficult to point out the precise epocha of the origin of chemical science; but we find traces of its existence in the most remote ages. Agriculture, mineralogy, and all the arts which are indebted to it for their principles, were cultivated and enlightened. We behold the original nations, immediately succeeding the fabulous ages, surrounded by all the arts which supplied their wants; and we may compare chemistry to that famous river whose waters fertilize the lands they inundate, but whose sources are still to us unknown.

Egypt, which appears to have been the nurse of chemistry reduced to principles, was not slow in turning the applications of this science towards a chimerical end.

The first seeds of chemistry were soon changed by the passion of making gold. In a moment all the labours of operators were directed towards alchemy alone; the great object of study became fixed on an endeavour to interpret fables, allusions, hieroglyphics, &c.; and the industry of several centuries was consecrated to the enquiry after the philosopher's stone. But though we admit that the alchemists have retarded the progress of chemistry, we are very far from being disposed to any outrage on the memory of these philosophers: we allow them the tribute of esteem to which on so many accounts they are entitled. The purity of their sentiments, the simplicity of their manners, their submission to Providence, and their love for the Creator, penetrate with veneration all those who read their works. The profoundest views of genius are every where seen in their writings, allied with the most extravagant ideas. The most sublime truths are degraded by applications of the most ridiculous nature; and this astonishing contrast of superstition and philosophy, of light and darkness, compels us to admire them, even at the instant that we cannot withhold our censure. We must not confound the sect of alchemists, of whom we shall proceed to speak, with that crowd of impostors, that sordid multitude of operators at the furnace, whose researches were directed to the discovery of minds capable of being imposed upon, who fed the ambition of such weak minds by the deceitful hope of increasing their riches. This last class of vile and ignorant men has never been acknowledged by the true alchemists; and they are no more entitled to that name, than the vender of specifics on the stage to the honourable name of Physician.

The hope of the alchemist may indeed be founded on a slender basis; but the great man, the man of genius, even at the time when he is pursuing an imaginary object, knows how to profit by the phenomena which may present themselves, and derives from his labours many useful truths which would have escaped the penetration of ordinary men. Thus it is that the alchemists have successively enriched pharmacy and the arts with most of their compositions. The strong desire of acquiring riches has in all

times been a passion so general, that this single motive has been sufficient to lead many persons to the cultivation of a science which has more relation than any other to metals; which studies their nature more particularly, and appears to facilitate the means of composing them. It is known that the Abdarites did not begin to consider the sciences as an occupation worthy a reasonable man, until they had seen a celebrated philosopher enrich himself by speculations of commerce; and I do not doubt but that the desire of making gold has decided the vocation of several chemists. We are therefore indebted to alchemy for several truths, and for several chemical professors: but this obligation is small in comparison to the mass of useful truth which might have been afforded during the course of several centuries; if, instead of endeavouring to form the metals, the operations of chemists had been confined to analysing them, simplifying the means of extracting them, combining them together, working them, and multiplying and rectifying their uses.

The rage for making gold was succeeded by the seductive hope of prolonging life by means of chemistry. The persuasion was easily admitted, that a science which affords remedies for all disorders, might without effort succeed in affording a universal medicine. The relations which have been handed down to us of the long life of the ancients, appeared to be a natural effect of their knowledge in chemistry. The numerous fables of antiquity obtained the favour of being admitted among established facts; and the alchemists, after having exhausted themselves in the search after the philosopher's stone, appeared to redouble their efforts to arrive at an object still more chimerical. At this period the elixirs of life, the arcana, the polychrest medicines, had their origin; together with all those monstrous preparations, of which a few have been handed down even to our days.

The chimera of the universal medicine agitated the minds of most men in the sixteenth century; and immortality was then promised with the same effrontery as a Charlatan now announces his remedy for every disease. The people are easily seduced by these ridiculous promises;

but the man of knowledge can never be led to think that chemistry can succeed in reversing that general law of nature which condemns all living beings to renovation, and a continual circulation of decompositions and successive generations. This sect gradually became an object of contempt. The enthusiast Paracelsus, who, after having flattered himself with immortality, died at the age of forty-eight at an inn at Saltzburg, completed its disgrace.—From that moment the scattered remains of this sect united themselves, never more to appear again in public. The light which began to shine forth on all sides, rendered it necessary that they should have recourse to secrecy and obscurity; and thus at length chemistry became purified.

James Barner, Bohnius, Tachenius, Kunckel, Boyle, Crollius, Glafer, Glauber, Schroder, &c. appeared on the ruins of these two sects, to examine this indigested aggregate, and separate from the confused mass of phenomena, of truth and of error, every thing which could tend to enlighten the science. The sect of the adepts, urged on by the madness of immortality, had discovered many remedies; and pharmacy and the arts then became enriched with formulæ and compositions, whose operations required only to be rectified, and their applications better estimated.

Nearly at the same time appeared the celebrated Becher. He withdrew chemistry from the too narrow limits of pharmacy. He shewed its connection with all the phenomena of nature; and the theory of the formation of metals, the phenomena of fermentation, the laws of putrefaction, were all comprehended and developed by this superior genius. Chemistry was then directed to its true object: and Stahl, who succeeded Becher, reduced to certain general principles all the facts with which his predecessor had enriched the science. He spoke a language less enigmatical; he classed all the facts with order and method; and purged the science of that alchemic infection, to which Becher himself was too much attached. But if we consider how great are the claims of Stahl, and how few the additions which have been made to his doctrine until the middle of this century, we cannot but be aston-



ished at the small progress of the science. When we consult the labours of the chemists who have appeared since the time of Stahl, we see most of them chained down to the steps of this great man, blindly subscribing to all his ideas; and the labour of thinking appeared no longer to exist among them. Whenever a well-made experiment threw a gleam of light unfavourable to his doctrine, we see them torment themselves in a ridiculous manner to form a delusive interpretation. Thus it was that the increase of weight which metals acquire by calcination, though little favourable to the idea of the subtraction of a principle without any other addition, was nevertheless incapable of injuring this doctrine.

The almost religious opinion which enslaved all the chemists to Stahl, has no doubt been pernicious to the progress of chemistry. But the strong desire of reducing every thing to first principles, and of establishing a theory upon incomplete experiments, or facts imperfectly seen, did not admit of the smallest obstacles. From the moment that analysis had shewn some of the principles of bodies, the chemist thought himself in possession of the first agents of nature. He considered himself as authorized to regard those bodies as elements which appeared no longer susceptible of being decomposed. The acids and the alkalis performed the principal part in natural operations: and it appeared to be a truth buried in oblivion, that the term where the artist stops is not the point at which the Creator has limited his power; and that the last result of analysis does indeed mark the limits of art, but does not fix those of nature. We might likewise reproach certain chemists for having too long neglected the operations of the living systems. They confined themselves in their laboratories, studied no bodies but in their lifeless state, and were incapable of acquiring any knowledge but such as was very incomplete: for he who, in his researches, has no other object in view than that of ascertaining the principles of a substance, acts like a physician who should suppose he had acquired a complete notion of the human body by confining his studies to the dead carcase. But we must likewise observe that, in order to form a proper

notion of the phenomena of living bodies, it is necessary to possess the means of confining the gaseous principles which escape from bodies; and of analysing these volatile and invisible substances which combine together. Now this work was impossible at that time; and we ought to beware of imputing to men those errors which arise from the state of the times in which they lived.

It may perhaps be demanded, on this occasion, why chemistry was sooner known, and more generally cultivated, in Germany and in the North than in our kingdom. I think that many reasons may be given for this. In the first place, the scholars of Stahl and of Becher must have been more numerous, and consequently their instruction farther extended. Secondly, the working of mines having become a resource necessary to the governments of the North, has been singularly encouraged; and that chemistry which enlightens mineralogy must necessarily have participated in its encouragements \*.

The study of chemistry did not begin to be cultivated to advantage in France until the end of the last century. The first wars of Louis XIV. so proper to develop the talents of the artist, the historian, and the military man, appeared little favourable to the peaceable study of nature. The naturalist who in his researches sees union and harmony around him, cannot be an indifferent spectator of the

\* Since the French government has facilitated the study of mineralogy by the most superb establishments, we have beheld the taste for chemistry revive, the arts which have the working of metals for their object have been rendered more perfect, and the mines which have been wrought are more numerous. Mr. Sage has been more particularly assiduous and zealous to turn the favour of government towards this object. I have been a witness to the laborious attention of this chemist to effect this revolution. I have beheld the personal sacrifices he made to bring it forward. I have applauded his zeal, his motives, and his talents. The same sentiments still occupy my mind; and though I teach a doctrine at present which is different from his, this circumstance arises from the impossibility of commanding opinions. The philosopher who is truly worthy of this name, is capable of distinguishing the friend of his heart from the slave of his system: and, in a word, every one ought to write according to his conviction; the most sacred axiom of the sciences being, "*Amicus Plato, sed magis amica veritas.*"

continual scenes of disorder and destruction; and his genius is crushed in the midst of troubles and agitations. The mind of the great Colbert, deeply penetrated with these truths, quickly endeavoured to temper the fire of discord, by turning the minds of men towards the only objects which could secure the peace and prosperity of the state. He exerted himself to render trade flourishing: he established manufactories: learned men were invited from all parts, encouraged, and united together, to promote his vast projects. Then it was that the ardour of enquiry replaced for a time the fury of conquest; and France very soon stood in competition with all nations for the rapid progress of the sciences, and the perfection of the arts. Lemery, Homberg, and Geoffroy arose nearly at the same time; and other nations were no longer entitled to reproach us for the want of chemists. From that moment the existence of the arts appeared to be well assured. All the sciences which afford their first principles, were cultivated with the greatest success: and it will scarcely be credited that, in the space of a few years, the arts were drawn from a state of non-entity; and carried to such a degree of perfection, that France, which had before received every thing from foreign countries, became in possession of the glory of supplying its neighbours with models and with merchandizes.

Chemistry and natural history, however, at the beginning of this century, were cultivated only by a very small number of persons; and it was then thought that the study of these sciences ought to be confined to the academies. But two men, whose names will be ever famous, have rendered the taste general under the reign of Louis XV. The one possessed that noble spirit which is a stranger to the power of prejudice, that indefatigable ardour which so easily overcomes every obstacle, that openness of character which inspires confidence, and transfused into the minds of his pupils that enthusiasm of which he himself felt the force. While Rouelle enlightened the science of chemistry, Buffon prepared a revolution still more astonishing in natural history. The naturalists of the North had succeeded in causing their productions to be read by a

small number of the learned; but the works of the French naturalist were soon, like those of nature, in the hands of the whole world. He possessed the art of diffusing through his writings that lively interest, that enchanting colouring, and that delicate and vigorous touch, which influence, attach, and subdue the mind. The profundity of his reasoning is every where united to all that agreeable illusion which the most brilliant imagination can furnish. The sacred fire of genius animates all his productions; his systems constantly exhibit the most sublime prospects in their totality, and the most perfect correspondence in their minute parts: and, even when he exhibits mere hypotheses, we are inclined to persuade ourselves that they are established truths. We become like the artist who, after having admired a beautiful statue, used his efforts to persuade himself that it respired, and removed every thing which could dissipate his illusion. We take up his work with a pleasure resembling that of the man who turns again to sleep, in hopes of prolonging the deception of an agreeable dream.

These two celebrated men, by diffusing the taste for chemistry and natural history, by making their relations and uses better known, conciliated the favour of government towards them; and from that moment every one interested himself in the progress of both sciences. Those persons who were best qualified in the kingdom, hastened to promote the revolution which was preparing. The sciences soon inscribed in their list of cultivators the beloved and respected names of La Rochefoucault, Aven, Chaulnes, Lauraguais, Malesherve, &c.; and these men, distinguished by their birth, were honoured with a new species of glory, which is independent of chance or prejudice. They enriched chemistry with their discoveries, and associated their names with all the other literati who pursued the same career. They revived in the mind of the chemist that passion for glory, and that ardour for the public good, which continually excite new efforts. The man of ambition and intrigue no longer endeavoured to depress the modest and timid man of genius. The credit of men in place served as a defence and support against



calumny and persecution. Recompences were assigned to merit. Learned men were dispatched into all parts of the world, to study the arts, and collect their productions. Men of the first merit were invited to instruct us with regard to our own proper riches; and establishments of chemistry which were made in the principal towns of the kingdom, diffused the taste for this science, and fixed among us those arts which we might in vain have attempted to naturalize, if a firm basis had not been first laid. The professors established in the capital, and in the provinces, appeared to be placed between the academies and the people, to prepare the latter for those truths which flow from such respectable associations. We may consider them as a medium which refracts and modifies the rays of light that issue from those various luminous centres; and directs them towards the manufactories, to enlighten and improve their practice. Without these favours, without this consideration and these recompences, could it have been expected that the most unassuming among philosophers would have exerted himself to promote the reputation of a people to whom he was unknown? Could a man so situated reasonably hope to succeed in carrying a discovery into effect? Is it probable that he should have possessed a sufficient fortune to work in the large way, and by this means alone to overcome the numberless prejudices which banish men of science from manufactories? The contemplative sciences demand of the sovereign repose and liberty only; but experimental sciences demand more, for they require assistance and encouragement. What indeed could be hoped in those barbarous ages, wherein the chemist scarcely durst avow the nature of the occupation which in secret constituted his greatest pleasure. The title of Chemist was almost a reproach: and the prejudice which confounded the professors of this science with such wretched projectors as are entitled only to pity, has probably kept back the revival of the arts for several centuries; for chemistry alone can afford them a proper basis. If the princes of past times had been friends of the arts, and jealous to acquire a pure and durable reputation; if they had been careful to honour the learned, to collect their

valuable labours and to transmit to us without alteration the precious annals of human genius; we should have been dispensed from labouring among the rubbish of early times, to consult a few of those remains which have escaped the general wreck; and we should have been spared the regret of allowing, after many useless researches, that the master-pieces of antiquity which remain answer scarcely any other purpose than to give us an idea of that superiority to which the earlier nations had arrived. Time, the sword, fire, and prejudice have devoured all; and our researches serve only to add to our regret for the losses which the world has sustained.

The science of chemistry possesses the glory, in our days, not only of having obtained the protection of government, but it may likewise boast of another equally elevated. This science has fixed the attention, and formed the occupation, of various men in whom the habit of a profound study of the accurate sciences had produced a necessity of admitting nothing but what is proved, and of attaching themselves only to such branches of knowledge as are susceptible of strict proofs. Messrs. De la Grange, Condorcet, Vander Monde, Monge, De la Place, Meusnier, Cousin, the most celebrated mathematicians of Europe, are all interested in the progress of this science, and most of them daily add to its progress by their discoveries.

So great a mass of instruction, and such ample encouragement, could not but effect a revolution in the science itself; and we are indebted to the combined efforts of all these learned men for the discovery of several metals, the creation of various useful arts, the knowledge of a number of advantageous processes, the working of several mines, the analysis of the gases, the decomposition of water, the theory of heat, the doctrine of combustion; and a mass of knowledge so absolute and so extended, respecting all the phenomena of art and of nature, that in a very short time chemistry has become a science entirely new. We might now say with much more truth what the celebrated Bacon affirmed of the chemistry of his time: "A new philosophy," says he, "has issued from the

furnaces of the chemists, which has confounded all the reasonings of the ancients.”

But while discoveries became infinitely multiplied in chemistry, the necessity of remedying the confusion which had so long prevailed, was soon seen, and indicated the want of a reform in the language of this science. There is so intimate a relation between words and facts, that the revolution which takes place in the principles of a science ought to be attended with a similar revolution in its language: and it is no more possible to preserve a vicious nomenclature with a science which becomes enlightened, extended, and simplified, than to polish, civilize, and instruct uninformed man without making any change in his natural language. Every chemist who wrote on any subject was struck with the inaccuracy of the words in common use, and considered himself as authorized to introduce some change; insomuch that the chemical language became insensibly longer, more confused, and more unpleasant. Thus carbonic acid has been known, during the course of a few years, under the names of Fixed Air, Aerial Acid, Mephitic Acid, Cretaceous Acid, &c.; and our posterity may hereafter dispute whether these various denominations were not applied to different substances. The time was therefore come, in which it was necessary to reform the language of chemistry: the imperfections of the ancient nomenclature, and the discovery of many new substances, rendered this revolution indispensable. But it was necessary to defend this revolution from the caprice and fancy of a few individuals; it was necessary to establish this new language upon invariable principles: and the only means of insuring this purpose was doubtless that of erecting a tribunal in which chemists of acknowledged merit should discuss the words received without prejudice and without interest; in which the principles of a new nomenclature might be established and purified by the severest logic; and in which the language should be so well identified with the science, the word so well applied to the fact, that the knowledge of the one should lead to the knowledge of the other. This

was executed in 1788 by Messrs. De Morveau, Lavoisier, Berthollet, and De Fourcroy.

In order to establish a system of nomenclature, bodies must be considered in two different points of view, and distributed into two classes; namely, the class of simple substances reputed to be elementary, and the class of combined substances.

1. The most natural and suitable denominations which can be assigned to simple substances, must be deduced from a principal and characteristic property of the substance intended to be expressed. They may likewise be distinguished by words which do not present any precise idea to the mind. Most of the received names are established on this last principle, such as the names Sulphur, Phosphorus, which do not convey any signification in our language, and produce in our minds determinate ideas only, because usage has applied them to known substances. These words, rendered sacred by use, ought to be preserved in a new nomenclature; and no change ought to be made, excepting when it is proposed to rectify vicious denominations. In this case the authors of the New Nomenclature have thought it proper to deduce the denomination from the principal characteristic property of the substance. Thus, pure air might have been called Vital Air, Fire Air, or Oxigenous Gas; because it is the basis of acids, and the aliment of respiration and combustion. But it appears to me that this principle has been in a small degree departed from when the name of Azotic Gas was given to the atmospherical mephitic—1. Because, none of the known gaseous substances excepting vital air being proper for respiration, the word Azote agrees with every one of them except one; and consequently this denomination is not founded upon an exclusive property, distinctive and characteristic of the gas itself. 2. This denomination being once introduced, the nitric acid ought to have been called Azotic Acid, and its combinations Azotates; because the acids are proposed to be denoted by the name which belongs to their radical. 3. If the denomination of Azotic Gas does not agree with this æriform substance, the name



of Azote agrees still less with the concrete and fixed substance; for in this state all the gases are essentially azotes. It appears to me therefore that the denomination of Azotic Gas is not established according to the principles which have been adopted; and that the names given to the several substances of which this gas constitutes one of the elements, are equally removed from the principles of the Nomenclature. In order to correct the Nomenclature on this head, nothing more is necessary than to substitute to this word a denomination which is derived from the general system made use of; and I have presumed to propose that of Nitrogene Gas. In the first place, it is deduced from the characteristic and exclusive property of this gas, which forms the radical of the nitric acid. By this means we shall preserve to the combinations of this substance the received denominations, such as those of the Nitric Acid, Nitrates, Nitrites, &c. In this manner the word which is afforded by the principles adopted by the celebrated authors of the Nomenclature, causes every thing to return into the order proposed to be established.

2. The method made use of to ascertain the denominations suitable to compound substances, appears to me to be simple and accurate. It has been thought that the language of this part of science ought to present the analyses; that the words should be only the expression of facts; and that consequently the denomination applied by a chemist to any substance which has been analysed, ought to render him acquainted with its constituent parts. By following this method, the Nomenclature is as it were united, and identified with the science; and facts and words agree together. Two things are therefore united, which until this time appeared to have no mutual relation, the word, and the substance which it represented; and by this means the study of chemistry is simplified. But when we apply these incontestable principles to the various objects of chemistry, we ought to follow the analysis step by step, and upon this ground alone establish general and individual denominations. We ought to observe that it is from this analytical method that the various denominations have been assigned, and that the methodical distri-

butions of natural history have been at all times made. If man were to open his eyes for the first time upon the various beings which people or compose this globe, he would establish their relation upon the comparison of their most evident properties, and no doubt would found his first divisions upon the most sensible differences. The various modes of existence, or their several degrees of consistence, would form his first division; and he would arrange them under the heads of solid, liquid, or aëriform bodies. A more profound examination, and a more connected analysis of the individuals, would soon convince him that the substances which certain general relations had induced him to unite in the same class, under a generic denomination, differed very essentially among each other, and that these differences necessarily required subdivision. Hence he would divide his solid bodies into stones, metals, vegetable substances, animal substances, &c; his liquids would be divided into water, vital air, inflammable air, mephitic air, &c. When he proceeded to carry his researches on the nature of these substances still farther, he would perceive that most of the individuals were formed by the union of simple principles; and here it is that his applications of the system to be followed, in assigning a suitable denomination to each substance, would begin. To answer this purpose, the authors of the New Nomenclature have endeavoured to exhibit denominations which may point out the constituent principles. This admirable plan has been carried into execution as far as relates to substances which are not very complicated, such as the combinations of the principles with each other; the acids, earths, metals, alkalis, &c. And this part of the Nomenclature appears to me to leave nothing more to be desired. The explanation may be seen in the work published on this subject by the authors, and in the Elementary Treatise of Chemistry of Mr. Lavoisier. I shall therefore do nothing more in this place than present a sketch of the method I have followed; taking for example the combinations of acids, which form the most numerous class of compounds.



The first step consisted in comprehending under a general denomination the combination of an acid with any given basis ; and in order to observe a more exact arrangement, and at the same time to assist the memory, one common termination has been given to all words which denote the combination of an acid. Hence the words Sulphates, Nitrates, Muriates, are used to denote combinations of the sulphuric, nitric, and muriatic acids. The kind of combination is denoted by adding to the generic word the name of the body which is combined with the acid ; thus, the sulphate of pot-ash expresses the combination of the sulphuric acid with pot-ash.

The modifications of these same acids, dependant on the proportions of their constituent principles, form salts different from those we have just spoken of ; and the authors of the New Nomenclature have expressed the modifications of the acids by the termination of the generic word. The difference in the acids arises almost always from the greater or less abundance of oxigene. In the first case, the acid assumes the epithet of Oxigenated ; hence the oxigenated muriatic acid, the oxigenated sulphuric acid, &c. In the second case, the termination of the word which denotes the acid, ends in *ous* ; hence the sulphureous acid, the nitrous acid, &c. The combinations of these last form sulphites, nitrites, &c. ; the combinations of the former compose oxigenated muriates, oxigenated sulphates, &c.

The combinations of the various bodies which compose this globe are not all as simple as those here mentioned ; and it may be immediately perceived how long and troublesome the denominations would be, if attempts were made to bestow a single denomination which should denote the constituent principles of a body formed by the union of five or six principles. In this case, the preference has been given to the received appellation, and no other changes have been admitted but such as were necessary in order to substitute proper appellations instead of those which afforded notions contrary to the nature of the objects they were applied to.

I have adopted this Nomenclature in my lectures, and in my writings; I have not failed to perceive how very advantageous it is to the teacher, how much it relieves the memory, how greatly it tends to produce a taste for chemistry, and with what facility and precision the ideas and principles concerning the nature of bodies fix themselves in the minds of the auditors. But I have been careful to insert the technical terms used in the arts, or received in society, together with these new denominations. I am of opinion that, as it is impossible to change the language of the people, it is necessary to descend to them, and by that means render them partakers of our discoveries. We see, for example, that the artist is acquainted with the sulphuric acid by no other name than that of Oil of Vitriol, though the name of the Vitriolic Acid has been the language of chemists for a century past. We cannot hope to be more happy in this respect than our predecessors; and, so far from separating ourselves from the artist by a peculiar language, it is proper that we should multiply the occasions of bringing us together; so far from attempting to enslave him by our language, we ought rather to inspire his confidence by learning his terms. Let us prove to the artist that our relations with him are more extended than he imagines; and let us by this intimacy establish mutual correspondence, and a concurrence of information, which cannot but redound to the advantage of the arts and of chemistry.

After having explained the principal objections which have retarded the improvement of chemistry, and the causes which in our time have accelerated its progress, we shall endeavour to point out the principal applications of this science; in which attempt, we think, we shall succeed best by casting a general retrospect over those arts and sciences which receive certain principles from it.

Most of the arts are indebted to accident for their discovery. They are in general neither the fruit of research, nor the result of combination, but all of them have a more or less evident relation to chemistry. This science therefore is capable of clearing up their first principles, reform-

ing their abuses, simplifying their operations, and accelerating their progress.

Chemistry bears the same relation to most of the arts, as the mathematics have to the several parts of science which depend on their principles. It is possible, no doubt, that works of mechanism may be executed by one who is no mathematician; and so likewise it is possible to dye a beautiful scarlet without being a chemist: but the operations of the mechanic, and of the dyer, are not the less founded upon invariable principles, the knowledge of which would be of infinite utility to the artist.

We continually hear in manufactories of the caprices and uncertainty of operations; but it appears to me that this vague expression owes its birth to the ignorance of the workmen with regard to the true principles of their art. For nature itself does not act with determination and discernment, but obeys invariable laws; and the inanimate substance which we make use of in our manufactures, exhibits necessary effects, in which the will has no part, and consequently in which caprices cannot take place. Render yourselves better acquainted with the materials you work upon, we might say to the artists; study more intimately the principles of your art; and you will be able to foresee, to predict, and to calculate every effect. It is your ignorance alone which renders your operations a continual series of trials, and a discouraging alternative of success and disappointment.

The public, which continually exclaims that experience is better than science, encourages and supports this ignorance on the part of the artist; and it will not be remote from our object to attempt to ascertain the true value of these terms. It is very true, for example, that a man who has had a very long experience may perform operations with exactness; but he will always be confined to the mere manipulation. I would compare such a man to a blind person who is acquainted with the road, and can pass along it with ease, and perhaps even with the confidence and assurance of a man who sees perfectly well; but is at the same time incapable of avoiding accidental obstacles, incapable of shortening his way or taking the

most direct course, and incapable of laying down any rules which he can communicate to others. This is the state of the artist of mere experience; however long the duration of his practice may have been, as the simple performer of operations.

It may perhaps be replied, that artists have made very important discoveries in consequence of assiduous labour. This is indeed true, but the examples are very scarce; and we have no right to conclude, because we have seen men of genius without any mathematical theory execute wonderful works of mechanism, that the mathematics are not the basis, or that any one has a right to expect to become a great mechanic without a profound study of mathematical principles.

It appears to be generally admitted at present, that chemistry is the basis of the arts: but the artist will not derive from chemistry all the advantages he has a right to expect, until he has broken through that powerful barrier which suspicion, self-love, and prejudice have raised between the chemist and himself. Such philosophers as have attempted to pass this line, have frequently been repelled as dangerous innovators; and prejudice, which reigns despotically in manufactories, has not even permitted it to be thought that the processes were capable of improvement.

It is easy to shew the advantages which the arts might obtain from chemistry, by casting a retrospect over its applications to each of them in particular.

1. It appears, from the writings of Columella, that the ancients possessed a considerable extent of knowledge respecting agriculture, which was at that time considered as the first and noblest occupation of man. But when once the objects of luxury prevailed over those of necessity, the cultivation of the ground was left to the mere succession of practice, and this first of the arts became degraded by prejudices.

Agriculture is more intimately connected with chemistry than is usually supposed. It must be admitted that every man is capable of causing ground to bear corn; but what a considerable extent of knowledge is necessary to cause



it to produce the greatest possible quantity! It is not enough, for this purpose, to divide, to cultivate and to manure any piece of ground: a mixture is likewise required of earthy principles so well assorted, that it may afford a proper nourishment; permit the roots to extend themselves to a distance, in order to draw up the nutritive juices; give the stem a fixed base; receive, retain, and afford upon occasion, the aqueous principle, without which no vegetation can be performed. It is therefore essential to ascertain the nature of the earth, the avidity with which it seizes water, its force of retaining it, &c.; and these requisites point to studies which will afford principles not to be obtained by mere practice but slowly and imperfectly.

Every grain requires a peculiar earth. Barley vegetates freely among the dry remains of granite; wheat grows in calcareous earth, &c. And how can it be possible to naturalize foreign products, without a sufficient stock of knowledge to supply them with an earth similar to that which is natural to them?

The disorders of grain and forage, and the destruction of the insects which devour them, are objects of natural history and chemistry: and we have seen in our own times the essential art of drying and preserving grain, and all those details which are interesting in the preparation of bread, carried by the labours of a few chemists to a degree of perfection which seemed difficult to have been attained.

The art of disposing stables in a proper manner, that of chusing water adapted for the drink of domestic animals, the œconomical processes for preparing and mixing their food, the uncommon talent of supplying a proper manure suited to the nature of soils, the knowledge necessary to prevent or to repair the effects of blights—all come within the province of chemistry; and without the assistance of this science our proceeding would be painful, slow, and uncertain.

We may at present insist upon the necessity of chemistry in the various branches of agriculture with so much the

more reason, as government does not cease to encourage this first of arts by recompences, distinctions, and establishments ; and the views of the state are forwarded by the proposal of means to render this art flourishing. We see, with the greatest satisfaction, that, by a happy return of reflection, we begin to consider agriculture as the purest, the most fruitful, and the most natural source of our riches. Prejudices no longer tend to oppress the husbandman. Contempt and servitude are no longer the inheritance received for his incessant labours. The most useful and the most virtuous class of men is likewise that whose state is most minutely considered ; and the cultivator of the ground in France is at last permitted to raise his hands in a state of freedom to Heaven, in gratitude for this happy revolution.

2. The working of mines is likewise founded upon the principles of chemistry. This science alone points out and directs the series of operations to be made upon a metal, from the moment of its extraction from the earth until it comes to be used in the arts.

Before the chemical analysis was applied to the examination of stones, these substances were all denoted by superficial characters, such as colour, hardness, volume, weight, form, and the property of giving fire with the steel. All these circumstances had given rise to methods of division in which every other property was confounded ; but the successive labours of Pott, Margraaff, Bergmann, Scheele, Bayen, Dietrich, Kirwan, Lavoisier, De Morveau, Achard, Sage, Berthollet, Jerhard, Erhmann, Fourcroy, Mongez, Klaproth, Crell, Pelletier, De la Metherie, &c. by instructing us concerning the constituent principles of every known stone, have placed these substances in their proper situations, and have carried this part of chemistry to the same degree of precision as that which we before possessed respecting the neutral salts.

The natural history of the mineral kingdom, unassisted by chemistry, is a language composed of a few words, the knowledge of which has acquired the name of Mine-



ralogist to many persons. The words Calcareous Stone, Granite, Spar, Schorle, Feld Spar, Schistus, Mica, &c. alone compose the dictionary of several amateurs of natural history; but the disposition of these substances in the bowels of the earth, their respective position in the composition of the globe, their formation and successive decompositions, their uses in the arts, and the knowledge of their constituent principles, form a science which can be well known and investigated by the chemist only.

It is necessary therefore that mineralogy should be enlightened by the study of chemistry; and we may observe that, since these two sciences have been united, the labour of working mines has been simplified, metallic ores have been wrought with more intelligence, several new metallic substances have been discovered, individuals have opened mines in the provinces; and we have become familiar with a species of industry which seemed foreign, and almost incompatible with, our soil and our habits. Steel and the other metals have received in our manufactories that degree of perfection which had till lately excited our admiration, and humiliated our self-love. The superb manufacture of Creusot has no equal in Europe. Most of our works are supported by pit-coal; and this new combustible substance is so much the more valuable, as it affords us time to repair our exhausted woods, and as it is found almost every where in those barren soils which repel the ploughshare, and prohibit every other kind of industry. The eternal gratitude of this country is therefore due to Messrs. Jars, Dietrich, Duhamel, Monet, Genfanne, &c. who first brought us acquainted with these true riches. The taste for mineralogy, which has diffused itself within our remembrance, has not a little contributed to produce this revolution; and it is in a great measure owing to those collections of natural history, against which some persons have so much exclaimed, that we are indebted for this general taste. Our collections have the same relation to natural history, as books bear to literature and the sciences. The collection frequently is nothing more than

an object of luxury to the proprietor ; but in this very case it is a resource always open to the man who is desirous of beholding, and instructing himself. It is an exemplar of the works of nature, which may be consulted every moment ; and the chemist who runs over all these productions, and subjects them to analyses to ascertain their constituent principles, forms the precious chain which unites nature and art.

3. While the chemist attends to the nature of bodies, and endeavours to ascertain their constituent principles, the natural philosopher studies their external characters, and as it were their physiognomy. The object of the chemist ought therefore to be united to that of the philosopher, in order to acquire a complete idea of a body. What in fact shall we call Air or Fire, without the instruction of the chemist ? Fluids more or less compressible, ponderous, and elastic. What are the particulars of information which natural philosophy affords us concerning the nature of solids ? It teaches us to distinguish them from each other, to calculate their weight, to determine their figure, to ascertain their uses, &c.

If we cast our attention upon the numerous particulars which chemistry has lately taught us respecting air, water, and fire, we shall perceive how much the connection of these two sciences has been strengthened. Before this revolution, natural philosophy was reduced to the simple display of machines ; and this coquetry, by giving it a transient glare, would have impeded its progress, if chemistry had not restored it to its true destination. The celebrated chancellor Bacon compared the natural magic, or experimental philosophy, of his time, to a magazine in which a few rich and valuable moveables were found among a heap of toys. The curious, says he, is exhibited instead of the useful. What more is required to draw the attention of great men, and to form that transient fashion of the day which ends in contempt ?

The natural philosophy of our days no longer deserves the reproaches of this celebrated philosopher. It is a science founded on two bases equally solid. On the one

part, it depends on mathematical science for its principles; and, on the other, it rests upon chemistry. The natural philosopher will attend equally to both sciences.

The study of chemistry, in certain departments, is so intimately connected with that of natural philosophy, that they are inseparable; as, for example, in researches concerning air, water, fire, &c. These sciences very advantageously assist each other in other respects; and while the chemist clears minerals from the foreign bodies which are combined with them, the philosopher supplies the mechanical apparatus necessary for exploring them. Chemistry is inseparable from natural philosophy even in such parts as appear the most independent of it; such, for example, as optics, where the natural philosopher can make no progress but in proportion as the chemist shall bring his glass to perfection.

The connection between these two sciences is so intimate, that it is difficult to draw a line of distinction between them. If we confine natural philosophy to enquiries relative to the external properties of bodies, we shall afford no other object but the mere outside of things. If we restrain the chemist to the mere analysis, he will at most arrive at the knowledge of the constituent principles of bodies, and will be ignorant of their functions. These distinctions in a science which has but one common purpose, namely the complete knowledge of bodies, cannot longer exist; and it appears to me that we ought absolutely to reject them in all objects which can only be well examined by the union of natural philosophy and chemistry.

At the period of the revival of letters, it was of advantage to separate the learned, as it were, upon the road to truth; and to multiply the workshops, if I may use the expression to hasten the clearing away. But at present, when the various points are re-united, and the connection between the whole is seen, these separations, these divisions, ought to be effaced; and we may flatter ourselves that, by uniting our efforts, we may make a rapid progress in the study of nature. The meteors, and all the phenomena of which the atmosphere is the grand

theatre, can be known only by this re-union. The decomposition of water in the bowels of the earth, and its formation in the fluid which surrounds us, cannot but give rise to the most happy and the most sublime applications.

4. The connection between chemistry and pharmacy is so intimate, that these two sciences have long been considered as one and the same; and chemistry, for a long time, was cultivated only by physicians and apothecaries. It must be allowed that, though the chemistry of the present day, is very different from pharmacy, which is only an application of the general principles of this science, these applications are so numerous, the class of persons who cultivate pharmacy is in general so well informed, that it is not at all to be wondered at, that most apothecaries should endeavour to enlighten their profession by a serious study of chemistry, and by the happiest agreement unite the knowledge of both parts of science.

The abuses which, at the beginning of the present century, were made of the applications of chemistry to medicine, have caused the natural and intimate relations of this science with the art of healing to be mistaken. It would have been more prudent, no doubt, to have rectified its applications; but unfortunately we have too much ground to reproach physicians for going to extremes. They have, without restriction, banished that which they before received without examination; and we have seen them successively deprive their art of all the assistance it might obtain from the auxiliary sciences.

In order to direct with propriety the applications of chemistry to the human body, proper views must be adopted relating to the animal economy, together with accurate notions of chemistry itself. The results of the laboratory must be considered as subordinate to physiological observations. We should endeavour to enlighten the one by the other, and to admit no truth as established which is contradicted by any of these means of conviction. It is in consequence of a departure from these principles that the human body has been considered as a lifeless and passive



substance; and that the strict principles observed in the operations of the laboratory have been applied to this living system.

In the mineral kingdom, every thing is subjected to the invariable laws of the affinities. No internal principle modifies the action of natural agents; and hence it arises that we are capable of fortelling, producing or modifying the effects.

In the vegetable kingdom, the action of external agents is equally evident; but the internal organization modifies their effects, and the principal functions of vegetables arise from the combined action of external and internal causes. It was no doubt for this reason that the Creator disposed the principal organs of vegetation upon the surface of the plant, in order that the various functions might at the same time receive the impressions of external agents, and that of the internal principle of the organization.

In animals the functions are much less dependant on external causes; and nature has concealed the principal organs in the internal parts of their bodies, as if to withdraw them from the influence of foreign powers. But the more the functions of an individual are connected with its organization, the less is the empire of chemistry over them; and it becomes us to be cautious in the application of this science to all the phenomena which depend essentially upon the principles of life.

We must not, however, consider chemistry as foreign to the study and practice of medicine. This science alone can teach us the difficulty and art of combining remedies. This alone can teach us to apply them with prudence and firmness. Without the assistance of this science, the practitioner would scarcely venture to apply those powerful remedies from which the chemical physician knows the means of deriving such great advantage. Chemistry alone in all probability, is capable of affording means of combating epidemic disorders, which in most cases are caused by an alteration in the air, the water, or our food. It will be only in consequence of analysis that the true remedy can be found against those stony concretions which form the matter of the gout, the stone, the rheumatism, &c.;

and the valuable particulars of information which we now possess respecting respiration, and the nature of the principal humours of the human body, are likewise among the benefits arising from this science.

5. Chemistry is not only of advantage to agriculture, physic, mineralogy, and medicine, but its phenomena are interesting to all the orders of men: the applications of this science are so numerous, that there are few circumstances of life in which the chemist does not enjoy the pleasure of seeing its principles exemplified. Most of those facts which habit has led us to view with indifference are interesting phenomena in the eyes of the chemist. Everything instructs and amuses him; nothing is indifferent to him, because nothing is foreign to his pursuits; and nature, no less beautiful in her most minute details than sublime in the disposition of her general laws; appears to display the whole of her magnificence only to the eyes of the chemical philosopher.

We might easily form an idea of this science, if it were possible to exhibit in this place even a sketch of its principal applications. We should see, for example, that chemistry affords us all the metals of which the uses are so extensive; that chemistry affords us the means of employing the parts of animals and of plants for our ornament; that our luxuries, and our subsistence, are by this science established as a tax upon all created beings; and that by this power we are taught to subject nature to our wants, our taste, and even to our caprices. Fire, that free independent element, has been collected and governed by the industry of the chemist; and this agent, destined to penetrate, to enliven, and to animate the whole of nature, has in his hands become the agent of death, and the prime minister of destruction. The chemists who in our time have taught us to insulate that pure air which alone is proper for combustion, have placed in our hands, as it were, the very essence of fire; and this element, whose effects were so terrible, becomes the agent of still more terrible consequences. The atmosphere, which was formerly considered as a mass of homogeneous fluid, is now found to be a true chaos, from which analysis has obtained



principles so much the more interesting to be known, as nature has made them the principal agents of her operations. We may consider this mass of fluid in which we live as a vast laboratory, in which the meteors are prepared, in which all the seeds of life and of death are developed, from which nature takes the elements of the composition of bodies, and to which their subsequent decomposition returns the same principles which were before extracted.

Chemistry, by informing us of the nature and principles of bodies, instructs us perfectly concerning our relation to the objects around us. This science teaches us, as it were, to live with them; and impresses a true life upon them, since by this means each body has its name, its character, its uses, and its influence, in the harmony and arrangement of this universe.

The chemist, in the midst of those numerous beings which the common race of men accuse nature of having vainly placed upon our globe, enjoys the prospect as it were in the centre of a society, all whose members are connected together by intimate relations, and concur to promote the general good. In his sight every thing is animated, every being performs a part on this vast theatre; and the chemist who participates in these interesting scenes, is repaid with usury for his first exertions to discover the relations existing between them.

We may even consider this commerce, or mutual relation between the chemist and nature, as very proper to soften the manners, and to impress on the character that freedom and firmness of principle so valuable in society. In the study of natural history, no cause ever presents itself to complain of inconstancy or treachery. An attachment is easily contracted for objects which afford enjoyment only; and these connections are as pure as their object, as durable as nature, and stronger in proportion to the exertions which have been required to establish them.

From all these considerations, there is no science which more eminently deserves to enter into the plan of a good education than chemistry. We may even affirm that the

study of this science is almost indispensably necessary to prevent us from being strangers in the midst of the beings and phenomena which surround us. It is true indeed that the habit of beholding the objects of nature may produce a knowledge of some of their principal properties. We may even in this way arrive at the theory of some of the phenomena. But nothing is more proper to check the pretensions of young persons who are elevated by such imperfect acquisitions, than to shew them the vast field of which they are ignorant. The profoundest sentiment of their ignorance will be seconded by the natural desire of acquiring new knowledge. The wonderful properties of the objects presented to them will engage their attention. The interesting nature of the phenomena will tend to excite their curiosity. Accuracy of experiment, and strictness of result, will form their reasoning powers, and render them severe in their judgment. By studying the properties of all the bodies which surround him, the young scholar learns to know their relation with himself; and by successively attending to all objects, he extends the circle of his enjoyment by new conquests. He becomes a partaker in the privileges of the Creator, by uniting and disuniting, by compounding and destroying. We might even affirm that the Author of nature, reserving to himself alone the knowledge of his general laws, has placed man between himself and matter, that it may receive these laws from his hands, and that he may apply them with proper modifications and restrictions. In this view, therefore, we may consider man as greatly superior to the other beings which compose this living system. They all follow a monotonous and invariable process; receive the laws, and submit to effects without modification. Man alone possesses the rare advantage of knowing a part of these laws, of preparing events, of predicting results, of producing effects at pleasure, of removing whatever is noxious, of appropriating whatever is beneficial, of composing substances which nature herself never forms; and, in this last point of view, himself a Creator, he appears to partake with the Supreme Being in the most eminent of his prerogatives.

# *Elements of Chemistry.*

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## PART THE FIRST.

### CONCERNING THE CHEMICAL PRINCIPLES.

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#### INTRODUCTION.

Definition of Chemistry; its Object and Means—Description of a Laboratory, and the principal Instruments employed in chemical Operations, with a Definition of those Operations.

**C**HEMISTRY is a science, the object of which is to ascertain the nature and properties of bodies.

The methods used to obtain this knowledge are reducible to two; analysis and synthesis.

The principal operations of chemistry are performed in a place called a Laboratory.

A laboratory ought to be extensive and well aired, in order to prevent dangerous vapours from remaining, which are produced in some operations, or which may escape by any unforeseen accident. It ought to be dry, because otherwise iron vessels would rust, and most of the chemical products would be liable to change. But the principal excellence of a laboratory consists in its being furnished with all those instruments which may be employed in the study of the nature of bodies, and in enquiries respecting their properties.

Among these instruments there are some which are of general use, and applicable to most operations; and there are others which serve only for peculiar uses. This division immediately points out that, at the present instant, we can only treat of the former, and that we must

## *The Evaporatory Furnace.*

to be made either on such occasions as will render it necessary to treat of their uses.

The chemical instruments most frequently employed are those which present themselves first to view upon entering a laboratory; namely, the furnaces.

These furnaces consist of earthen vessels appropriated to the various operations performed upon bodies by means of fire.

A proper mixture of sand and clay is commonly the material of which these vessels are formed. It is difficult, and even impossible, to prescribe and determine, according to any invariable method, the proportions of these constituent parts; because they must be varied according to the nature of the earth made use of. Habit and experience alone can furnish us with principles on this subject.

The several methods of applying fire to substances under examination, has occasioned the construction of furnaces in different forms, which we shall at present reduce to the three following.

I. The evaporatory furnace.—This furnace has received its name from its use. It is used to reduce liquid substances into vapour by means of heat, in order to separate the more fixed principles from those which are more ponderous; and were mixed, suspended, compounded, or dissolved in the fluid.

The fire-place is covered by the evaporatory vessel. Two or three grooves, channels, or depressions are made in the sides of the furnace near its upper edge, to facilitate the drawing of the fire.

The vessel which contains the substance to be evaporated, is called the evaporatory vessel.

These vessels are formed of earth, glass or metal. Vessels of unglazed earth are too porous, insomuch that liquids filtrate through their texture. Those of porcelain biscuit are likewise penetrable by liquids strongly heated, and suffer gaseous or æriform substances to escape. The beautiful experiments of Mr. D'Arcet upon the combustion and destruction of the diamond, in balls of porcelain, are well known, and tend to illustrate this subject. I have confirmed these results by experiments in the large way,



upon the distillation of aqua-fortis, which loses as well in quality as quantity when the process is carried on in vessels of porcelain clay.

Glazed earthen vessels cannot be used when the glass consists of the calces of lead or copper; because those metallic matters are attacked by acids, fats, oils, &c. Neither can earthen vessels be used which are covered with enamel, because this kind of opaque glass is almost always full of small cracks, through which the liquid would introduce itself into the body of the vessel.

Earthen vessels cannot therefore be used, excepting in operations of little delicacy, in which precision and accuracy are not indispensably required.

Evaporatory vessels of glass are in general to be preferred. Those which resist the fire better than any others, are prepared in the laboratory, by cutting a sphere of glass or a receiver into two equal parts with a red-hot iron. The capsules which are made in the glass-house are thickest at the bottom, and consequently are more liable to break at that part when exposed to the fire.

Evaporatory vessels of metal are used in manufactories. Copper is most commonly employed, because it not only possesses the property of resisting fire, but has a considerable degree of solidity, together with the facility of being wrought. Alembics are made of this metal, for the distillation of vinous spirits, and aromatic substances; as are also caldrons or pots for the crystallization of certain salts, and for several dying processes, &c. Lead is likewise of considerable use, and is made choice of whenever operations are to be performed upon substances which contain the sulphuric acid, such as the sulphates of alumine and of iron; and for the concentration and rectification of the oil of vitriol. Tin vessels are also employed in some operations: the scarlet bath affords a more beautiful colour in boilers of this metal than in those of any other. Capitals of tin have already begun to be substituted in the room of those of copper, in the construction of alembics; and by this means the several products of distillation are exempted from every suspicion of that dangerous metal. Boilers of iron are likewise used for certain



coarse operations ; as, for example, in the concentration of the lixiviums of common salt, of nitre, &c.

Evaporatory vessels of gold, of silver, or of platina, are to be preferred in some delicate operations ; but the price and scarcity of these vessels do not permit them to be used, especially in the large way.

Moreover it is from the nature of the substance to be evaporated, that we must determine the choice of the vessel most suitable to any operation. There is no particular kind of vessel which can be adapted exclusively on all occasions. It may only be observed, that glass presents the greatest number of advantages, because it is composed of a substance the least attacked, the least soluble, and the least destructible by chemical agents.

Evaporatory vessels are known by the name of capsules, cucurbits, &c. according to their several forms.

These vessels ought in general to be very wide and shallow, in order that the distillation and evaporation may be speedy and æconomical. It is necessary, 1. That the evaporatory vessel be not narrow at its upper part. 2. That the heat be applied to the liquid in all parts, and equally. 3. That the column or mass of the liquid should have little depth, and a large surface of evaporation. It is upon these principles that I have constructed, in Languedoc, boilers proper for distilling brandy, which save eleven-twelfths of the time, and four-fifths of the combustibles.

Evaporation may be performed in three manners. 1. By a naked fire. 2. By the sand bath. 3. By the water bath.

Evaporation is made by a naked fire, when there is no substance interposed between the fire and the vessel which contains the liquid intended to be evaporated ; as, for example, when water is boiled in a pot.

Evaporation is performed by the sand bath, when a vessel filled with sand is interposed between the fire and the evaporatory vessel. The heat is in this case communicated more slowly and gradually ; and the vessels, which would otherwise have been broken by the immediate application of the heat, are enabled to resist its

force. The heat is at the same time more equally kept up; the refrigeration is more gradual; and the operations are performed with a greater degree of order, precision, and facility.

If, instead of employing a vessel filled with sand, we use a vessel of water, and the evaporatory vessel be plunged in the liquid, the evaporation is said to be made on the water bath: in this case, the substance to be evaporated is only heated by communication from the water. This form or method of evaporation is employed when certain principles of great volatility, such as alcohol, or the aromatic principles of plants, are to be extracted or distilled. It possesses the advantage of affording products which are not changed by the fire, because the heat is transmitted to them by the intervention of a liquid: it is this circumstance which renders the process valuable for the extraction of volatile oils, perfumes, etherial liquids, &c. It possesses the advantage of affording a heat nearly equal, because the degree of ebullition is a term nearly constant; and this standard heat may be graduated or varied at pleasure, by adding salts to the liquid of the water bath, because this single circumstance renders the ebullition more or less quick and easy. The same effect may likewise be produced by restraining the evaporation; for in this case the liquid may assume a degree of heat much more considerable, as is seen in the digester of Papin, steam engines, colipiles, and the boilers for striking the red tinge in cotton.

Sublimation differs from evaporation, because the substance to be raised is solid. The vessels used in this operation are known by the name of sublimatory vessels. These are commonly globes terminating in a long neck: they are then called matrasses.

In order to sublime any substance, a part of the ball of the matrass is surrounded with sand. The matter which is volatilized by the heat, rises, and is condensed against the coldest part of the vessel; where it forms a stratum or cake, that may be taken out by breaking the vessel itself. In this manner it is that sal ammoniac, cor-

rosive sublimate, and other similar products, are formed for the purposes of commerce.

Sublimation is usually performed either for the purpose of purifying certain substances, and disengaging them from extraneous matters; or else to reduce into vapour, and combine under that form, principles which would have united with great difficulty if they had not been brought to that state of extreme division.

II. The reverberatory furnace.—The name of the reverberatory furnace has been given to that construction which is appropriated to distillation.

This furnace is composed of four parts. 1. The ash-hole, intended for the free passage of the air, and to receive the ashes or residue of the combustion. 2. The fire-place, separated from the ash-hole by the grate, and in which the combustible matter is contained. 3. A portion of a cylinder, which is called the laboratory, because it is this part which receives the retorts employed in the operations or distillations. 4. These three pieces are covered with a dome, or portion of a sphere, pierced near its upper part by an aperture, which affords a free passage to the current of air, and forms a chimney. The most usual form of the reverberatory furnace is that of a cylinder terminated by a hemisphere, out of which arises a chimney of a greater or less length, to produce a suitable degree of aspiration.

In order that a reverberatory furnace may be well proportioned, it is necessary, 1. That the ash-hole should be large, to admit the air fresh and unaltered. 2. That the fire-place and laboratory together should have the form of a true ellipsis, whose two foci should be occupied by the fire and the retort. In this case all the heat, whether direct or reflected, will strike the retort.

The reverberatory furnace is used for distillation. Distillation is that process by which the force of fire is applied to disunite and separate the several principles of bodies, according to the laws of their volatility, and their several affinities.

Distilling vessels are known by the name of retorts.

Retorts are formed of glass, of stone-ware, of porcelain, or of metal; these substances being respectively used, according to the nature of the bodies intended to be exposed to distillation.

Whatever be the nature of the material, the forms of retorts are the same. This figure resembles an egg, terminating in a beak or tube, which diminishes insensibly in diameter, and is slightly inclined or bended.

The oval portion of the retort, which is called its belly, is placed in the laboratory of the furnace, and is supported upon two bars of iron, which separate the laboratory from the fire-place; while the beak or neck of the retort issues out of the furnace through a circular aperture formed in the edges of the dome and of the laboratory.

A vessel intended to receive the product of the distillation is fitted to the neck of the retort. This vessel is called the recipient, or receiver.

The receiver is commonly a sphere with two apertures; the one of considerable magnitude, to receive the neck of the retort; the other smaller, to afford vent for the vapours. This part is called the tubulure of the receiver; whence the terms tubulated receiver, or receiver not tubulated, &c.

Though the reverberatory furnace be particularly adapted to distillation, this operation may be performed on the sand-bath; and here, as in other cases, it depends singly on the intelligence of the artist to vary his apparatus according to the necessity of circumstances, and the nature of the substances upon which he operates.

The construction of these furnaces may likewise be varied; and the chemist will find it necessary to learn the art of availing himself of every apparatus he possesses, to carry his operations into execution: for if he should persuade himself that it is impossible to proceed in chemical research, excepting in a laboratory provided with all suitable vessels; he may let the moment pass in which a discovery might be made, but which may not again return. And it may truly be said, that he who treads servilely in the paths of others who have gone before him, will never attain to the discovery of new truths.



III. The forge furnace.—The forge furnace is that in which the current of air is determined by bellows. The ash-hole, the fire place, and the laboratory are here all united together and this assemblage forms only a portion of a cylinder, pierced near the lower angle by a small hole, into which the tube of the bellows enters. This part is sometimes covered with a hemisphere or dome, to concentrate the heat with greater efficacy, and to reflect it upon the bodies exposed to it. The forge furnace is employed in the fusion and calcination of metals, and generally for all the operations which are performed in crucibles.

By crucibles we understand vessels of earth or metal, which are almost always of the form of an inverted cone. A crucible ought to support the strongest heat without melting: it ought to resist the attacks of all such agents as are exposed to heat in vessels of this kind. Those crucibles which possess the greatest degree of perfection, are made in Hesse or in Holland. I have made very good ones by a mixture of raw and unbaked clay from Salavas in the Vivarais.

Our laboratories have been provided with crucibles of platina, which unite the most excellent properties. They are nearly infusible, and at the same time indestructible by the fire.

The several earthen vessels concerning which we have here treated, may be fabricated by the hand, or wrought in the lathe. The first proceeding renders them more solid, the clay is better united, and it is the only method used in glass manufactories; but the second method is more expeditious.

The agent of such decompositions as are effected by means of furnaces, is fire. It is afforded by the combustion of wood, pit-coal, or charcoal.

Wood is only employed in certain large works; and we prefer charcoal in our laboratories, because it does not smoke, has no bad smell, and burns better in small masses than other combustibles. We choose that which is the most sonorous, the driest, and the least porous.



But, in the several operations we are about to describe, it is necessary to defend the retorts from the immediate action of the fire; and also to coerce and restrain the expansible vapours, which are very elastic, and frequently corrosive. It is to answer these purposes that various lutes are employed.

1. A glass retort exposed to the action of the fire would infallibly break, if the operator were not to have recourse to the prudent precaution of coating it with earth.

I have found it advantageous for the coating of retorts, to use a mixture of fat earth and fresh horse dung: for this purpose, the fat earth is suffered to rot for some hours in water; and when it is moistened, and properly softened, it must be kneaded with the horse dung, and formed into a soft paste, which is to be applied and spread with the hand upon every part of the retort intended to be exposed to the action of the fire. The horse dung combines several advantages. 1. It contains a serous fluid, which hardens by heat, and strongly connects all the parts together: when this juice has been altered by fermentation or age, the dung does not possess the same virtue. 2. The filaments or stalks of hay, which are so easily distinguished in horse dung, unite all the parts of the lute together.

Retorts luted in this manner resist the impression of the fire very well; and the adhesion of the lute to the retort is such, that even should the retort fly during the operation, the distillation may be still carried on, as I have daily experience in works in the large way.

2. When it is required to coerce or oppose the escape of the vapours which are disengaged during any operation it is no doubt sufficient if the joinings of the vessels be covered with paper glewed on, or with slips of bladder moistened with the lute of lime and white of egg, provided the vapours be neither dangerous nor corrosive; but, when the vapours are corrosive, it is necessary to use the fat lute to retain them.

Fat lute is made with boiled linseed oil mixed and well incorporated with sifted clay. Nut oil, kneaded with the same clay, forms a lute possessing the same properties. It is easily extended in the hand, and is used for

defending the joinings of vessels, upon which it is afterwards secured by strips of linen, dipped in the lute of lime and white of egg. Before the application of heat in any distillation, it is necessary first to suffer the lutes to dry. Without this precaution, the vapours would rise and escape; or otherwise they would combine with the water which moistens the lutes, and would corrode and destroy the bladder, the skin, the paper, and in a word every substance used to secure them in their places. The lute of lime and white of egg dries very speedily, and must be used the moment it is made. This lute, likewise, opposes the greatest resistance to the escape of the vapours, and adheres the most intimately to the glass. It is made by mixing a small quantity of finely-powdered quick-lime with white of egg, and afterwards beating up the mixture to facilitate the combination. It must then be instantly applied on pieces of old linen, to be wrapped round the places of joining.

In the large works, where it is not possible to attend to all these minute details, the joinings of the retort and receiver are luted together with the same lute which is used to coat the retorts. A covering of the thickness of a few lines is sufficient to prevent the vapours of the marine or nitrous acid from escaping.

As in certain operations a disengagement takes place of so prodigious a quantity of vapours, that it is dangerous to confine them; and as, on the other hand, the suffering them to escape would occasion a considerable loss in the product; an apparatus has been contrived of great ingenuity and simplicity to moderate the issue, and to retain without risk such vapours as would otherwise escape. This apparatus is known by the name of its author, Mr. Woulfe, a famous English chemist. His most excellent process consists in adapting the extremity of a recurved tube to the tubulure of the receiver; the other end of which is plunged into water, in a bottle half filled, and properly placed for that purpose. From the empty part of this bottle issues a second tube, which is in like manner plunged in the water of a second bottle. A number of other bottles may be added, observing the

same precautions; with the attention, nevertheless, to leave the last open, to give a free escape to the vapours which are not coercible; and, when the apparatus is thus disposed, all the joinings are to be luted. It will easily be imagined that the vapours which escape from the retort are obliged to pass through the tube adapted to the tubulure of the receiver, and consequently must pass through the water of the first bottle: they therefore suffer a first resistance, which partly condenses them. But as almost all vapours are more or less miscible and soluble in water, a calculation is previously made of the quantity of water necessary to absorb the vapours which are disengaged from the mixture in the retort; and care is taken to distribute this proper quantity of water in the bottles of the apparatus.

By this means we obtain the purest and most concentrated products; because the water, which is always the receiver, and is the vehicle of these substances, becomes saturated with them. There is, perhaps, no other method of obtaining products always of an equal energy, and comparable in their effects; a circumstance of the greatest importance in the operations of the arts, as well as in philosophical experiments.

I have applied this apparatus to works in the large way; and I use it to extract the common muriatic acid, the oxygenated muriatic acid, ammoniac or volatile alkali, &c.

As it would very often happen, in this apparatus, that the pressure of the external air would cause the water of the outer vessels to pass into the receiver, in consequence of the simple refrigeration of the retort; this inconvenience has been obviated, by inserting a straight tube into the necks of the first and the second bottles, to such a depth, that its lower end is plunged into the water, while its other end rises several inches above the neck of the bottle. It may easily be conceived, as a consequence of this disposition, that when the dilated vapours of the receiver and retort are condensed by cooling, the external air will rush through these tubes to establish the equilibrium; and water cannot pass from the one to the other.



Before the invention of this apparatus, it was usual to drill a hole in the receiver, which was kept closed, and only opened from time to time for the escape of the vapours. This method was inconvenient in many respects. In the first place, and principally, because, in spite of all precautions, it was attended with the risk of an explosion every moment, by the irregular disengagement of the vapours, and the impossibility of calculating the quantity produced in a given time. A second inconvenience was, that the vapours which thus escaped occasioned a considerable loss in the product, and even weakened the remainder; because this volatile principle consisted of the strongest part. A third inconvenience was, that the vapours which did escape incommoded the artist to such a degree, that it was impossible to perform most of the operations of chemistry in the course of a lecture, where a considerable number of auditors were present.

Thus it is that the apparatus of Woulfe unites a number of advantages: on the one hand, economy in the processes, and superiority in the product; on the other hand, safety for the chemist and his assistants: and in every point of view the author is entitled to the best acknowledgments of chemists, who were too often so much affected with these unwholesome exhalations, that their health was either totally destroyed, or they fell absolute victims to their zeal for the promotion of science.

It is necessary that a laboratory should be provided with balances of the utmost accuracy; for the chemist, who very frequently operates only upon small quantities, ought to be able by the strictness of his operations, and the accuracy of his apparatus, to produce results comparable with those of works in the large way. It frequently happens that the simple essay of a specimen of an ore determines the opening of a mine: and it scarcely need be pointed out, of how great consequence it is to remove every cause of error from the operations of chemistry; since the slightest error in the works of the laboratory may be attended with the most unhappy consequences, when the application of the principles is made to works in the large way.

We shall treat of other vessels and of the chemical apparatus, in proportion as we shall have occasion to make use of them; for it appears to us that, by thus connecting the description with their use, we shall succeed better in rendering them intelligible to the reader, at the same time that his memory will be less fatigued.

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## SECTION I.

Concerning the General Law which tends to bring the Particles of Bodies together, and to maintain them in a State of Mixture or Combination.

THE Supreme Being has given a force of mutual attraction to the particles of matter; a principle which is alone sufficient to produce that arrangement which the bodies of this universe present to our observation. As a very natural consequence of this primordial law, it follows that the elements of bodies must have been urged towards each other; that masses must have been formed by their re-union; and that solid and compact bodies must have insensibly been constituted; towards which, as towards a centre, the less heavy and less compact bodies must gravitate.

This law of attraction, which the chemists call Affinity, tends continually to bring principles together which are disunited, and retains with more or less energy those which are already in combination; so that it is impossible to produce any change in nature, without interrupting or modifying this attractive power.

It is natural, therefore, and even indispensable, that we should speak of the law of the affinities before we proceed to treat of the methods of analysis.

Affinity is exercised either between principles of the same nature, or between principles of a different nature.



We may, therefore, distinguish two kinds of affinity, with respect to the nature of bodies. 1. The affinity of aggregation, or that which exists between two principles of the same nature. 2. The affinity of composition, or that which retains two or more principles of different natures in a state of combination.

*Of the Affinity of Aggregation.*

Two drops of water which unite together into one, form an aggregate, of which each drop is known by the name of an integrant part.

An aggregate differs from a heap; because the integrant parts of this last have no perceptible adhesion to each other; as, for example, a heap of barley, of sand, &c.

An aggregate and a heap differ from a mixture; because the constituent parts of this last are of a different nature; as, for example, in gun-powder.

The affinity of aggregation is stronger, the nearer the integrant parts approach to each other; so that every thing which tends to separate or remove these integrant parts from each other, diminishes their affinity, and weakens their force of cohesion.

Heat produces this effect upon most known bodies: hence it is that melted metals have no consistence. The caloric, or matter of heat, by combining with bodies, almost always produces an effect opposite to the force of attraction; and we might consider ourselves as authorised to affirm that it is a principle of repulsion, if sound chemistry had not proved that it produces this effect only by its endeavour to combine with bodies, and thereby necessarily diminishing their force of aggregation, as all other chemical agents do. Besides which, the extreme levity of caloric produces the effect that, when it is combined with any given body, it continually tends to elevate it, and to overcome that force which retains it, and precipitates it towards the earth.

The mechanical operations of pounding, of hammering, or of cutting, likewise diminish the affinity of aggregation. They remove the integrant parts to a distance

from each other; and this new disposition, by presenting a less degree of adhesion, and a larger surface, facilitates the immediate action, and augments the energy, of chemical agents. It is for this purpose that bodies are divided when they are to be analysed, and that the effect of re-agents is facilitated by the action of heat.

The mechanical division of bodies is more difficult, the stronger their aggregation.

Aggregates exist under different states; they are solid, liquid, aëriform, &c.—See Fourcroy's Chemistry.

#### Of the Affinity of Composition.

Bodies of different kinds exert a tendency or attraction upon each other, which is more or less strong; and it is by virtue of this force that all the changes of composition or decomposition observed amongst them, are effected.

The affinity of composition exhibits invariable laws in all the phenomena it causes. We may state these laws as general principles; to which may be referred all the effects presented to our observation by the action of bodies upon each other.

I. The affinity of composition acts only between the constituent parts of bodies.

The general law of attraction is exerted upon the masses; and in this respect it differs from the law of the affinities, which does not perceptibly act but on the elementary particles of bodies. Two bodies placed near each other do not unite; but, if they be divided and mixed, a combination may arise. We have examples of this when the muriate of soda, or common salt, is triturated with litharge; the muriate ammoniac, or common sal ammoniac, with lime, &c. And it may be asserted that the energy of the affinity of composition is almost always proportioned to the degree of the division of bodies.

II. The affinity of composition is in the inverse ratio of the affinity of aggregation.

It is so much the more difficult to decompose a body, as its constituent principles are united or retained by a greater force. Gases, and especially vapours, continually

tend to combination, because their aggregation is weak: and nature, which is constantly renewing the productions of this universe, never combines solid with solid; but, reducing every thing into the form of gas, by this means breaks the impediments of aggregation; and these gases uniting together, form solids in their turn.

Hence, no doubt, it arises, that the affinity of composition is so much the more strong as bodies approach nearer to the elementary state; and we shall observe, on this subject, that this law of nature is founded in wisdom: for if the force or affinity of composition did not increase in proportion as bodies were brought to this degree of simplicity; if bodies did not assume a decided tendency to unite and combine, in proportion as they approach to their primitive or elementary state; the mass of elements would continually increase by these successive and uninterrupted decompositions; and we should insensibly return again to that chaos or confusion of principles, which is supposed to have been the original state of this globe.

The necessity of this state of division, which is so proper to increase the force of affinity, has caused it to be admitted as an incontestable principle, that the affinity of composition does not take place, unless one of the bodies be in the fluid state: *corpora non agunt nisi sint fluida*. But it seems to me that extreme division might be substituted instead of dissolution; for both these operations tend only to attenuate bodies, without altering their nature. It is by virtue of this division, which is equivalent to dissolution, that the decomposition of muriate of soda is effected by trituration with minium, as well as the union of cold and dry alkali with antimony, and the disengagement of volatile alkali by the simple mixture of sal ammoniac with lime.

III. When two or more bodies unite by the affinity of composition, their temperature changes.

This phenomenon cannot be explained but by considering the fluid of heat as a constituent principle of bodies, unequally disturbed amongst them; so that, when any change is produced in bodies, this fluid is displaced in its turn, which necessarily produces a change of temperature.

We shall return to these principles when we speak of heat.

IV. The compound which results from the combination of two bodies, possesses properties totally different from those of its constituent principles.

Some chemists have affirmed, that the properties of compounds were intermediate between those of their constituent parts. But this term "intermediate" has no meaning in the present case; for what intermediate qualities can exist between sour and sweet, or between water and fire?

If we attend ever so little to the phenomena which are exhibited to us by bodies in their composition, we shall perceive that their form, their taste, and their consistence, are changed in combination; and we cannot establish any rule to indicate, *a priori*, all the changes which may arise, and the nature and properties of the body which shall be formed.

V. Every individual substance has its peculiar affinities with the various substances presented to it.

If all bodies had the same degree of affinity with each other, no change could take place amongst them: we should not be able to displace any principle by presenting one body to another. Nature has therefore wisely varied the affinities, and appointed to each body its relation with all those that can be presented to it.

It is in consequence of this difference in the affinities that all chemical decompositions are effected: all the operations of nature and art are founded upon it. It is therefore of importance to be well acquainted with all the phenomena and circumstances which this law of decomposition can present to us.

The affinity of composition has received different names, according to its effects. It is divided into simple affinity, double affinity, the affinity of an intermedium, reciprocal affinity, &c.

I. Two principles united together, and separated by means of a third, afford an example of simple affinity: it consists in the displacing of one principle by the addition



of a third. Bergman has given it the name of Elective Attraction.

The body which is disengaged, or displaced, is known by the name of the Precipitate. An alkali precipitates metals from their solutions; the sulphuric acid precipitates the muriatic, the nitric, &c.

The precipitate is not always formed by the disengaged substance. Sometimes the new compound itself is precipitated; as, for example, when I pour the sulphuric or vitriolic acid on a solution of muriate of lime. Sometimes the disengaged body and the new compound are precipitated together; as, for example, when the sulphate of magnesia or Epsom salt is dissolved in water, and precipitated by means of lime-water.

2. It often happens that the compound of two principles cannot be destroyed either by a third or a fourth body separately applied; but if these two bodies be united, and placed in contact with the same compound, a decomposition or change of principles will then take place. This phenomenon constitutes the double affinity. An example will render this proposition more clear and precise. The sulphate of pot-ash or vitriolated tartar is not completely decomposed by the nitric acid or by lime, when either of these principles is separately presented; but, if the nitric acid be combined with lime, this nitrate of lime will decompose the sulphate of pot-ash. In this last case the affinity of the sulphuric acid with the alkali is weakened by its affinity to the lime. This acid, therefore, is subject to two attractions; the one which retains it to the alkali, and the other which attracts it towards the lime: Mr. Kirwan has named the first the Quiescent Affinity, and the other the Divellent Affinity. The same may be said respecting the affinities of the alkali; it is retained to the sulphuric acid by a superior force, but nevertheless attracted by the nitric acid. Let us suppose, now, that the sulphuric acid adheres to the alkali with a force as 8, and to the lime by a force expressed by the number 6; that the nitric acid adheres to the lime by a force as 4, and tends to unite with the alkali by a force as



7. It may then be perceived that the nitric acid and the lime, separately applied to the sulphate of pot-ash, would not produce any change: but if they be presented in a state of combination, then the sulphuric acid is attracted on the one hand by 6, and retained by 8; it has therefore an effective attraction to the alkali as 2. On the other hand, the nitric acid is attracted by a force as 7, and retained by a force as 4; it therefore retains a tendency to unite with the alkali, which is denoted by the number 3; and consequently it ought to displace the sulphuric acid, which is retained only by a force as 2.

3. There are cases in which two bodies, having no perceptible affinity to each other, obtain a disposition to unite by the intervention of a third; and this is called the affinity of an intermedium. An alkali is the intermedium of union between oil and water; hence the theory of lixiviums, of washings, &c. &c.

If the affinities of bodies were well known, we might foretel the results of all operations: but it is obvious how difficult it must be to acquire this extensive knowledge of nature; more especially since modern discoveries have exhibited to us an infinity of modifications in our processes, and have shewn that results may vary with such facility, that even the absence or presence of light will render them very different.

As long as chemistry was confined to the knowledge of a few substances, and was busied only in attending to a certain number of facts, it was possible to draw up tables of affinity, and to exhibit the result of our knowledge in one and the same table. But all the principles upon which these tables have been constructed, have received modifications; the number of principles has increased; and we find ourselves under the necessity of labouring upon new ground. A sketch of this great work may be seen in the Essay on Affinities of the celebrated Bergman, and in article Affinity in the *Encyclopédie Méthodique*.

VI. The particles which are brought together and united by affinity, whether they be of the same nature or of different natures, continually tend to form bodies of a polyhedral, constant, and determinate form,

This beautiful law of nature, by which she impresses on all her productions a constant and regular form, appears to have been unknown to the ancients: and when chemists began to discover that almost all bodies of the mineral kingdom affected regular forms, they at first distinguished them according to the inaccurate resemblance supposed to exist between them and other known bodies. Hence the denomination of crystals in pyramids, needles, points of diamonds, crosses, sword blades, &c.

We are more particularly indebted to the celebrated Linnæus for the first precise ideas of these geometrical figures. He took notice of the constancy and uniformity of this character; and this celebrated naturalist thought himself authorised to make it the basis of his method of classification of the mineral kingdom.

Mr. Romé de Lisle has proceeded still farther: he has subjected all the forms to a strict examination; he has, as it were, decomposed them; and is of opinion that he can distinguish in the crystals of all analogous or identical substances, the simple modifications and shades of a primitive form. By this means he has reduced all the confused and irregular forms to certain primitive figures; and has attributed to nature a plan or primitive design, which she varies and modifies in a thousand manners, according to circumstances that influence her proceedings. This truly great and philosophical work has rendered this part of mineralogy in the highest degree interesting; and if we should admit that Mr. De Lisle has perhaps carried these resemblances too far, we cannot but allow that he deserves a distinguished place amongst those authors who have contributed to the progress of science. The *Crytallographie* of this celebrated naturalist may be perused with advantage.

The abbé Haüy has since applied calculation to observation. He has undertaken to prove that each crystal has a nucleus or primitive form; and has shewn the laws of diminution to which the component laminae of the crystals are subject, in their transition from the primitive to the secondary forms. The development of these fine principles, and their application to crystals the best known,

may be seen in his theory of the structure of crystals, and in several of his memoirs printed in the volumes of the Academy of Sciences.

The united labours of these celebrated naturalists have carried crystallography to a degree of perfection of which it did not appear susceptible. But we shall, at this moment, attend only to the principles according to which crystallization is effected.

To dispose a substance to crystallization, it is necessary in the first place to reduce it to the most complete state of division.

This division may be effected by solution, or by an operation purely mechanical.

Solution may be effected either by the means of water or of fire. The solution of salts is in general performed in the first liquid, that of metals is effected by means of the second; and their solution is not complete until a degree of heat is applied of sufficient intensity to convert them into the state of gas.

When the water which holds any salt in solution is evaporated, the principles of the dissolved body are insensibly brought nearer to each other, and it is obtained in regular form. The same circumstance nearly takes place in the solution by fire. When a metal is impregnated with this fluid, it does not crystallize but in proportion as this excess of igneous fluid is withdrawn.

In order that the form of a crystal may be regular, three circumstances are required; time, a sufficient space, and repose. Consult Linnæus, Daubenton, &c.

A. Time causes the superabundant fluid to be slowly dissipated, and brings the integral parts nearer each other by insensible gradation, and without any sudden shock. These integrant parts therefore unite according to their constant laws, and form a regular crystal. For this reason it is, that slow evaporation is recommended by all good chemists. Vide Stahl's Treatise on salts, chap. 29.

In proportion as the evaporation of the solvent is effected, the principles of the dissolved body approach each other, and their affinity is continually augmented while that of the solvent remains unaltered. Hence it arises,

no doubt, that the last portions of the solvent are most difficultly volatilized, and that salts retain a greater or less quantity, which forms their water of crystallization. The proportion of water of crystallization not only varies greatly in the different salts, but it adheres with greater or less strength. There are some which suffer this water to fly off when they are exposed to the air; such as soda or the mineral alkali, the sulphate of soda or Glauber's salt, &c. In this situation these salts lose their transparency, and fall into powder: they are then said to have effloresced. There are other salts which obstinately retain their water of crystallization; such as the muriate of pot-ash, the nitrate of pot-ash or common nitre, &c.

The phenomena presented to us by the different salts, when forcibly deprived of their water of crystallization, exhibit other varieties. Some crackle with the heat, and are thrown about in small pieces when the water is dissipated; this appearance is called decrepitation. Others emit the same water in the form of steam, and are liquefied with a diminution of their bulk. Others again swell up, and become converted into a blistered or porous substance.

We are indebted to Mr. Kirwan for an accurate table of the water of crystallization contained in each salt. This table may be seen by consulting his *Mineralogy*.

The simple cooling of the fluid which holds the salt in solution may precipitate a considerable quantity. The caloric and the water dissolve a greater quantity of salt when their action is united; and it may easily be imagined that the subtraction of one of the solvents must occasion the precipitation of that portion which it held in solution. Thus it is that warm water saturated with salt, must suffer a part to precipitate by cooling; and for this reason crystallization always begins at the surface of the liquid, and on the sides of the containing vessel; namely, because these parts are the first which suffer refrigeration.

It is the alternation of heat and cold which causes the atmosphere to dissolve sometimes a greater, and sometimes a less quantity of water; and constitutes mists, the evening dew, &c.



The mutual approach of the constituent parts of a body held in solution may be likewise accelerated by presenting to the water which suspends them, another body which has a stronger affinity to it. It is upon this principle that alcohol precipitates several salts.

B. Space or sufficient room is likewise a condition necessary for obtaining regular crystallization. If nature be restrained in her operations, the product of her labour will exhibit symptoms of this state of constraint. It may be asserted that nature forms her productions according to all the circumstances which may influence her operations.

C. A state of repose in the fluid is likewise necessary to obtain very regular forms. Uninterrupted agitation opposes all symmetrical arrangement; and in this case the crystallization obtained will be confused and indeterminate.

I am persuaded that, in order to obtain bodies under the form of crystals, a previous solution is not necessary, but that a simple mechanical division would be sufficient. To obtain a conviction of this truth, it is only necessary to observe that solution does not change the nature of bodies, but simply procures an extreme state of division; so that the disunited principles approaching each other very gradually, and without starts, can adapt themselves to each other, by following the invariable laws of their gravity and affinity. Now a division purely mechanical produces the same effect, and places the principles in the same disposition. We ought not therefore to be surpris'd if most salts, such as gypsum, when dispersed in the earth, should assume regular forms without any previous solution; neither ought we to think it strange if the imperceptible fragments of quartz, of spar, &c. when carried along and prodigiously divided by the action of waters, should be deposited in the form of regular crystals.

A very singular property may be observed in salts; which may be referred to crystallization, but is likewise in some measure remote from it, because it does not depend upon the same causes. This is the property of rising along the sides of the vessels which contain the solution. It is known by the name of Saline Vegetation.



I have first demonstrated that this phenomenon depends on the concurrence of air and light; and that the effect may be determined at pleasure towards any part of the vessel, by managing and directing the action of these two agents.

I have shewn the principal forms which this singular vegetation affects. The detail of my experiments may be seen in the third volume of the Memoirs of the Academy of Toulouse.

Mr. Dorthes has confirmed my results; and has moreover observed that camphor, spirits of wine, water, &c. which rise by insensible evaporation in half-filled vessels, constantly attach themselves to the most enlightened parts of the vessels.

Messrs. Petit and Rouelle have treated on the vegetation of salts; but a series of experiments on the subject was wanting. This is what we have endeavoured to supply.

## SECTION II.

Concerning the various Means employed by Chemists to overcome the Adhesion which exists between the Particles of Bodies.

THE law of affinities, towards which our attention has been directed, tends continually to bring the particles of body into contact, and to maintain them in their state of union. The efforts of the chemist are almost all directed to overcome this attractive power, and the means he employs are reducible to—1. The division of bodies by mechanical operations. 2. The division or separation of the particles from each other by the assistance of solvents. 3. The means of presenting to the several principles of the same bodies, substances which have a stronger affinity to them than those principles have to each other.

I. The different operations performed upon bodies by the chemist, to determine their nature, alter their form, their texture, and even in some instances change their constitution. All these changes are either mechanical or chemical.

The mechanical operations we shall at present describe, do not change the nature of substances, but in general change only their form and bulk. These operations are performed by the hammer, the knife, the pestle, &c. Whence it follows, that the chemical laboratory ought to be provided with all these instruments.

These divisions or triturations are performed in mortars of stone, of glass, or of metal. It is the nature of the substance under examination which determines the use of one or the other of these vessels.

The object of these preliminary operations is, to prepare and dispose bodies for new operations which may disunite their principles and change their nature; these last-mentioned operations, which may be distinguished by the appellation Chemical, are what most essentially constitute the analysis.

II. The solution to which we are at present to attend, consists in the division and disappearance of a solid in a liquid, but without any alteration in the nature of the body so dissolved.

The liquid in which the solid disappears, is called the solvent or menstruum.

The agent of solution appears to follow certain constant laws, which we shall here point out.

A. The agent of solution does not appear to differ from that of affinity; and in all cases the solution is more or less abundant, the greater the affinity of the integrant parts of the solvent is to those of the body to be dissolved.

From this principle it follows, that, to facilitate solution, it is necessary that bodies should be triturated and divided. By this means a greater number of surfaces are presented, and the affinity of the integrant parts is diminished.

It sometimes happens that the affinity between the solvent and the body presented to it has so little energy,

that it does not become perceptible till after a considerable interval of time. These slow operations, of which we have some examples in our laboratories, are common in the works of nature; and it is probably to similar causes that we ought to refer most of those results whose causes or agents escape our perception or observation.

B. Solution is more speedy in proportion as the body to be dissolved presents a greater surface: on this principle is founded the practice of pounding, triturating, and dividing bodies intended to be dissolved. Bergman has even observed, that bodies which are not attacked in considerable masses, become soluble after minute division. Letters on Iceland, p. 421\*.

C. The solution of a body constantly produces cold. Advantage has even been taken of this phenomenon to procure artificial cold, much superior to the most rigorous temperature ever observed in our climates. We shall again advert to this principle when we come to treat of the laws of heat.

The principal solvents employed in our operations are water, alcohol, and fire. Bodies submitted to one or the other of these solvents present similar phenomena; they are divided, rarefied, and at last disappear: the most refractory metal melts, is dissipated in vapour, and passes to the state of gas, if a very strong heat be applied to it. This last state forms a complete solution of the metallic substance in the caloric.

The effect of caloric is often united with one of the other solvents, to accomplish a more speedy and abundant solution.

The three solvents here mentioned do not exercise an equal action on all bodies indiscriminately. Skillful chemists have exhibited tables of the dissolving power of these menstruums. We may see, in the Mineralogy of Kirwan, with what care that celebrated chemist has exhibited the degree of solubility of each salt in water. The table of Mr. De Morveau may likewise be consulted

\* Von Troil's Letters, quoted by Mr. Bergman. T.

on the dissolving power of alcohol. *Journal de Physique*, 1785.

Most authors who have treated of solution have considered it in too mechanical a point of view. Some have supposed sheaths in the solvent, and points in the body dissolved. This absurd and gratuitous supposition has appeared sufficient to account for the action of acids upon bodies. Newton and Gassendi have admitted pores in water, in which salts might insinuate themselves; and have by this means explained why water does not augment in its bulk in proportion to the quantity of salt it takes up. Gassendi has even supposed pores of different forms; and has endeavoured to shew by this means how water saturated with one salt may dissolve others of another kind. Dr. Watson, who has observed the phenomena of solution with the greatest care, has concluded from his numerous experiments; 1. That the water rises in the vessel at the moment of the immersion of the salt. 2. That it falls during the solution. 3. That it rises after the solution above the original level. The two last effects seem to me to arise from the change of temperature which the liquor undergoes. The refrigeration arising from the solution must diminish the volume of the solvent; but it ought to return to its first state as soon as the dissolution is finished. The tables of Dr. Watson respecting these phenomena, and the specific gravity of water saturated with different salts, may be consulted in the *Journal de Physique*, vol. xiii. p. 62\*.

III. As the peculiar affinities of bodies to each other are various, the constituent principles may be easily disengaged by other substances; and it is upon this consideration that the action of all the re-agents employed by chemistry in its analysis is founded. Sometimes the chemist displaces certain principles, which he can in that state examine more accurately, because insulated, and disengaged from all their combinations. It frequently happens that the re-agent made use of combines with some principle of the body analysed; and a compound arises,

\* Or in the fifth vol. of his *Chemical Essays*. T.



whose characters indicate to us the nature of the principle which has thus entered into combination, because the combinations of the principal re-agents with various bases are well known. It likewise frequently happens that the re-agent made use of is itself decomposed, which circumstance renders the phenomena and the products more complicated; but we are enabled from the nature of these products to form a judgment of the component parts of the body analysed. This last fact was little attended to by the ancient chemists; and this is one of the principal defects of the labours of Stahl, who has referred most of those phenomena to the bodies which he submitted to analysis, which in reality arose only from the decomposition of the re-agents employed in his operations.

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### SECTION III.

Concerning the Method of Proceeding which the Chemist ought to follow in the Study of the various Bodies presented to us by Nature.

THE progress made in any science depends upon the solidity of those principles which form its basis, and upon the method of studying them. It is not, therefore, to be wondered at, that chemistry made but little progress in those times, when the language of chemists was enigmatical, and when the principles of the science were founded only on analogies falsely deduced, or on a few facts illy understood. In the times which have followed this epocha, the facts have indeed been more attended to; but, instead of suffering them to speak for themselves chemists have been desirous of making applications, drawing consequences, and establishing theories. Thus it was that Stahl, when he first observed that oil of vitriol and charcoal produced sulphur, if he had then confined himself to the simple relation of the fact, he would have an-



nounced a valuable and eternal truth; but when he concluded that the sulphur was produced by the combination of the inflammable principle of the charcoal with the oil of vitriol, he asserted that which the experiment does not point out: then it was that he proceeded further than the facts warranted; and this first rash step might be a first step towards error. All doctrine, in order to be lasting, ought to consist of the pure and simple expression of facts: but we are almost always governed by our imaginations; we adapt the facts to our manner of seeing them, and thus we are misled by ourselves. The prejudice of self-love afterwards furnishes us with various means to avoid recantation; we exert ourselves to draw our successors into the same paths of error; and it is not till after much time has been lost, after many vain conjectures have been exhibited and after we have the strongest convictions that it is impossible to bend the nature of things to our caprices and unfounded ideas, that some superior mind disengages itself from the delusion; and returning to experiment, and the nature of things, suffers himself to be led no further than he is authorized by these to proceed.

We may affirm, to the honour of our contemporaries, that facts are at present discussed by a much severer logic; and it is to this vigorous method of investigation and discussion that we are indebted for the rapid progress of chemistry. It is in consequence of this dialectic march that we have at length arrived to the practice of attending to all the principles which are combined or disengaged in the operations of nature and art. We keep an account of all the circumstances which have a more or less considerable influence on the results, and we deduce simple and natural consequences from the whole of the facts; by which means we create a science as strict in its principles as sublime in its applications.

This then is the moment to draw out a faithful sketch of the actual state of chemistry, and to collect in the numerous writings of modern chemists every thing which may serve to lay the foundation of this beautiful science.

Not many years ago, it was possible to present, in a few words, the whole of our knowledge of chemistry. It

was sufficient, at that time, to point out the methods of performing pharmaceutical operations; the processes of the arts were almost all enveloped in darkness, the phenomena of nature were all enigmatical; and it is only since this veil has begun to be removed that we have beheld the development of a collection of facts and researches referable to general principles, and forming a science entirely new. Then it was that a number of men of genius reviewed the whole, and attended to the improvement of chemical knowledge. Every step in their progress brought them nearer to the truth; and in a few years we have beheld a perspicuous doctrine arise out of the ancient chaos. Every event has appeared conformable to the laws they established; and the phenomena of art and nature are now explained with equal facility.

But in order to advance with speed in the career which has been thus opened, it is necessary to explain certain principles, according to which we may direct our steps.

In the first place, I think it proper to avoid that tedious custom which subjects the beginner in any science to the painful task of collecting all the opinions of various philosophers before he decides for himself. In reality, facts belong to all times, and are as unchangeable as nature herself, whose language they are. But the consequences deduced from them must vary according to the state of our acquired knowledge. It is eternally true for example, that the combustion of sulphur affords the sulphuric acid. It was believed, for a certain time, that this acid was contained in the sulphur; but our discoveries on the combustion of bodies ought to have led us to the deduction of a very different theory from that which presented itself to the earlier chemists. We ought, therefore, to attach ourselves principally to facts; or rather we ought to attach ourselves to the facts only, because the explanation which is given of them at remote times is very seldom suited to the present state of our knowledge.

The numerous facts with which chemistry has been successively enriched, form the first embarrassment of the student who is desirous of acquiring the elements of this science. In fact, what are the elements of a science? The

clear, simple, and accurate enunciation of those truths which form its basis. It is necessary, therefore, for the full accomplishment of this purpose, to analyse all the facts, and to exhibit a faithful and clear abridgment : but this method is impracticable on account of the numerous details, and the infinite number of discussions, into which it would lead us. The only proceeding, therefore, which appears to me to be practicable, is to exhibit the most decisive experiments, those which are the least contested, and to neglect those which are doubtful or inconclusive : for one experiment, well made, establishes a truth as incontestably as a thousand equally averred.

When a proposition is found to be supported by suspicious or contested facts, when opposite theories are built upon contradictory experiments, we must have the courage to discuss them, to repeat them, and to acquire a certainty of the truth by our own endeavours. But when this method of conviction is out of our power, we ought to weigh the degree of confidence which the defenders of the opposite facts are entitled to ; to examine whether analogous facts do not lead us to adopt certain results ; after which it becomes us to give our opinion with that modesty and circumspection, suitable to the greater or less degree of probability annexed to each opinion.

But when any doctrine appears to us to be established on experiments of sufficient validity, it then remains to be applied to the phenomena of nature and art. This, in my opinion, is the most certain touchstone to distinguish true principles from those which are without foundation. And when I observe that all the phenomena of nature unite, and conform themselves, as it were, to any theory, I conclude that this theory is the expression and the language of truth. When, for example, I behold that a plant can be supported by pure water alone, that metals are calcinable, that acids are formed in the bowels of the earth, have I not a right to conclude that the water is decomposed ? and do not the chemical facts which in our laboratories afford a testimony of its decomposition—do not these acquire a new force by the observation of the preceding phenomena ? I conclude, therefore, that we

ought to make a point of uniting these two kinds of proofs: and a principle deduced from experiment is not, in my opinion, demonstrable until I see that it may with facility be applied to the phenomena of art and nature. Hence, if I find myself in a state of hesitation between opposite systems, I will decide in favour of that whose principles and experiments adapt themselves naturally, and without force to the greatest number of phenomena. I will always distrust a single fact, which is applicable to no conclusion; and I will consider it as false, if it be in opposition to the phenomena which nature presents to us.

It appears to me likewise that he who professes to study, or even to teach chemistry, ought not to endeavour to arrive at or exhibit the whole which has been done in each department, or to follow the tedious progress of the human mind from the origin of a discovery to the present time. This fastidious crudition is fatiguing to the learner; and these digressions ought in no case to be admitted in the enunciation of science, excepting when the historical details afford interesting facts, or lead us by uninterrupted degrees to the present state of our knowledge. It rarely happens, however, that this kind of researches, this genealogy of science, affords us such characters; and it ought no more to be admitted, in general, that an elementary writer should bring together and discuss every thing which has been done in a science, than that he who undertakes to direct a traveller should previously enter into a long dissertation on all the roads which have been successively made, and on those which still exist, before he should point out the best and shortest way to arrive at the end of his journey. It may, perhaps, be said of the history of science, and more especially that of chemistry, that it resembles the histories of nations. It seldom affords any light respecting the present situation of affairs; exhibits many fables concerning past times; induces a necessity of entering into discussions upon the circumstances that pass in review; and supposes a mass of extraneous knowledge acquired on the part of the reader, which is independent of the purpose aimed at in the study of the elements of chemistry.



When these general principles, respecting the study of chemistry, are once well established, we may afterwards proceed in the chemical examination of bodies in two ways: we may either proceed from the simple to the compound, or we may descend from the compound to the simple. Both these methods have their inconveniences; but the greatest, no doubt, which is found in following the first method is, that, by beginning with the simplest bodies, we present substances to the consideration of the learner which nature very seldom exhibits in such a state of nakedness and simplicity; and we are forced to conceal the series of operations which have been employed to divest these substances from their combinations, and reduce them to the elementary state. On the other hand, if we present bodies to the view of the learner such as they are, it is difficult to succeed in an accurate knowledge of them; because their mutual action, and in general most of their phenomena, cannot be understood without the previous and accurate knowledge of their constituent principles, since it is upon these alone that they depend.

After having maturely considered the advantages and inconveniences of each method, we give the preference to the first. We shall therefore begin by giving an account of the several bodies in their most elementary state, or reduced to that term beyond which analysis can effect nothing; and, when we shall have explained their various properties, we will combine these bodies with each other, which will afford a class of simple compounds: and hence we shall rise by degrees to the knowledge of bodies, and the most complicated phenomena. We shall be careful, in any examination of the several bodies to which we shall direct our researches, to proceed from known to unknown; and our first attention shall be directed to elementary substances. But as it is impossible, at one and the same time, to treat of all those substances which the present state of our knowledge obliges us to consider as elementary, we shall confine ourselves to the exhibition of such as are of the greatest importance in the phenomena of the globe we inhabit, such as are almost universally spread over its surface, and such as enter as principles into the compo-

sition of the re-agents most frequently employed in our operations; such, in a word, as we continually find in the examination and analysis of the component parts of the globe. Light, heat, sulphur, and carbone are of this number. Light modifies all our operations, and most powerfully contributes to the production of all the phenomena which appertain to bodies either living or inanimate. Heat, distributed after an unequal proportion among all the bodies of this universe, establishes their various degrees of consistence and fixity; and is one of the great means which art and nature employ to divide and volatilize bodies, to weaken their force or adhesion, and by that means prepare them for analysis. Sulphur exists in the products of the three kingdoms; it forms the radical of one of the best known, and most generally employed, acids; it exhibits interesting combinations with most simple substances; and, under these several points of view, it is one of the substances the most necessary to be known in the first steps of chemical science. The same may be said of carbone; it is the most abundant fixed product found in vegetables and animals. Analysis has discovered it in some mineral substances. Its combination with oxigene is so common in bodies, and in the operations of art and nature, that there are scarcely any phenomena which do not present it to our view, and which consequently require the knowledge of its properties. From all these reasons it appears to us, that for the advancement of chemistry it is necessary our first proceeding should be founded on the knowledge of these substances; and that we should not direct our attention to other simple or elementary substances, accordingly as they present themselves,

## SECTION IV.

## Concerning Simple or Elementary Substances.

**I**F we cast an eye over the systems which have been successively formed by philosophers relative to the number and nature of the elements, we shall be astonished at the prodigious variety which prevails in their manner of thinking. In the earlier times, every one seems to have taken his own imagination for his guide ; and we find no reasonable system until the time when Aristotle and Empedocles acknowledged as elements, Air, Water, Earth, and Fire. Their opinion has been well received for many ages ; and it must be confessed that it is calculated to seduce the mind. There are, in fact, enormous masses, and inexhaustible stores, that present themselves to our view, of these four principles, to which the destruction or decomposition of bodies appeared to refer all the several component parts which formation or creation had taken from them. The authority of all those great men who had adopted this system, and the analysis of bodies which presented only these four principles, afforded sufficient grounds for admitting this doctrine.

But as soon as chemistry had advanced so far as to discover the principles of bodies, the professors of that science presumed to mark the number, nature, and character of the elements ; and every substance that was unalterable by the chemical methods of decomposition, was considered by them as a simple or elementary principle. By thus taking the limits of analysis as the term for indicating the elements, the number and the nature of these must vary according to the revolutions and the progress of chemistry. This has accordingly happened, as may be seen by consulting all the authors who have

written on this subject, from the time of Paracelsus to the present day. But it must be confessed that it is no small degree of rashness, to assume the extent of the power of the artist as a limit for that of the Creator, and to imagine that the state of our acquisitions is a state of perfect knowledge.

The denomination of Elements ought therefore to be effaced from a chemical nomenclature, or at least it ought not to be used but as an expression denoting the last term of our analytical results; and it is always in this sense that we shall use the word.

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## CHAPTER I.

### *Concerning Fire.*

THE principal agent employed by nature to balance the power and natural effect of attraction, is fire. By the natural effect of attraction we should possess none but solid and compact bodies; but the caloric unequally dispersed in bodies tends incessantly to destroy this adhesion of the particles; and it is to this principle that we are indebted for the varieties of consistence under which bodies present themselves to our observation. The various substances that compose this universe are therefore subjected, on the one hand, to a general law which tends to bring them together; and, on the other hand, to a powerful agent which tends to remove them from each other: it is upon the respective energy of these two forces that the consistence of all bodies depends. When the affinity prevails, they are in the solid state; when the caloric is most powerful, they are in the state of gas; and the liquid state appears to be the point of the equilibrium between these two powers.



It is therefore essentially necessary to treat of fire, since it acts so leading a part in this universe; and because it is impossible to treat of any substance whatever, without attending to the influence of this agent.

There are two things to be considered in fire—heat and light.

These two principles, which have been very often confounded, appear to be very distinct in their own nature; because they are scarcely ever proportional to each other, and because each can exist without the other.

The most usual acceptation of the word *Fire* comprehends heat and light; and its principal phenomena must have been known for a long time. The discovery of fire must have been nearly as ancient as the human species upon this globe. The shock of two flints, the action of meteors, or the effect of volcanos, must have afforded the earliest idea of it; and it is very astonishing that the inhabitants of the Marian Islands were not acquainted with its effects before the invasion of the Spaniards. These islanders, who became acquainted with this terrible element only in consequence of its ravages, considered it at first as a malevolent being which attached itself to all beings, and devoured them.—See the Abbé Raynal's *Histoire Philosophique*, &c.

The effects of fire are perhaps the most astonishing of any which nature exhibits; and we ought not to be surpris'd that the ancients considered it as an intermediate being between spirit and matter, and have built the beautiful fable of Prometheus upon its origin. We have had the happiness, in our time, to acquire well-founded and extensive ideas respecting this agent, which we shall proceed to develop in the two following articles.

## ARTICLE I.

### Concerning Caloric and Heat.

When a metal or a liquid is heated, these bodies are dilated in every direction, are reduced to vapour, and at last become invisible when the most powerful heat is applied to them.

Bodies which possess the principle of heat, part with it more or less readily. If we attentively observe a body during its cooling, a slight movement of undulation will be perceived in the surrounding air: an effect which may be compared to the phenomenon exhibited upon the mixture of two liquors of unequal density and weight.

It is difficult to conceive this phenomenon without admitting of a peculiar fluid, which passes first from the body which heats to that which is heated, combines with the latter, produces the effects we have spoken of, and afterwards escapes to unite with other bodies, according to its affinities, and the law of equilibrium, to which all bodies tend.

This fluid of heat, which we call Caloric, is contained in greater or less quantities in bodies, according to the greater or less degrees of affinity existing between it and them.

Various means may be employed to displace or disengage the caloric. The first is by the method of affinities: for example, water poured upon the sulphuric acid expels the heat, and takes its place; and while there is a disengagement of heat, the volume of the mixture does not increase in proportion to the bulk of the two substances mixed. This shews that penetration takes place, which cannot be explained but by admitting that the integrant parts of the water take the place of the caloric, in proportion as it is dissipated.---The second method of precipitating caloric, is by friction and compression. In this case it is expressed or squeezed out, in the same manner as water from a sponge. In reality, the whole of the heat which may be produced by friction, is not afforded by the body itself; because, in proportion as the interior heat is developed, the external air acts upon the body, calcines or inflames it, and itself gives out heat during its fixation. Fermentation, and in general every operation which changes the nature of bodies, may disengage caloric, because the new compound may demand and receive a greater or less quantity. Hence it is that chemical operations produce sometimes cold, and sometimes heat.

Let us now examine the form under which caloric presents itself.

This fluid is disengaged either in a state of liberty, or in a state of combination.

In the first case, the caloric always endeavours to obtain an equilibrium; not that it is distributed equally among all bodies, but it is dispersed among them according to the degrees of its affinity. Whence it follows, that the circumambient bodies receive and retain a quantity more or less considerable. Metals are easily penetrated by this fluid, and transmit it with equal facility; wood and animal substances receive it to the degree of combustion; liquids, until they are reduced to vapour. Ice alone absorbs all the heat communicated to it, without giving it out to other bodies until it has acquired the fluid state\*.

The degree of heat can be appreciated only by its effects: and the instruments which have been successively invented to calculate it, and are known by the names of thermometers, pyrometers, &c. have been applied to the strict determination of the several phenomena exhibited in consequence of the absorption of caloric in various bodies.

The dilatation of fluids, or of metals in the fluid state, by the several degrees of heat, has been long measured by thermometers formed of glass; but this very fusible substance can only be used to ascertain degrees of heat inferior to that which renders the glass itself fluid.

Several means have been successively proposed for calculating the higher degrees of heat. Mr. Leidenfrost has proved that the hotter a metal is, the more slowly will drops of water evaporate from its surface; and he has proposed this principle for the construction of pyrometers. A drop of water in an iron spoon, heated to the degree of boiling water, evaporates in one second; a similar drop, poured on melted lead, is dissipated in six or seven

\* The ingenious author has inadvertently been guilty of an oversight. Not only ice, but all other bodies, absorb heat, during liquefaction, as he himself shews hereafter. T.

seconds ; and upon red-hot iron in thirty. Mr. Ziegler, in his *Specimen de digestore Papini*, has found that 89 seconds were required to evaporate a drop of water at 520 degrees of Fahrenheit ; and that one second is sufficient at the 300th degree. This phenomenon, which is more interesting to chemistry than pyrometry, to which it will always afford results little susceptible of rigorous calculation, appears to me to depend upon the adhesion and decomposition of the water upon the metal.

The most accurate pyrometer we are acquainted with, is that which was presented to the Royal Society of London by Mr. Wedgwood. It is constructed upon the principle, that the purest clay shrinks in the fire in proportion to the heat applied to it. This pyrometer consists of two parts ; one called the gauge, which serves to measure the degrees of diminution or shrinking ; the other contains the simple pieces of pure clay, which are called thermometer pieces.

The gauge is formed of a plate of baked earth, upon which are applied two rulers or straight pieces of the same substance. These rulers, being perfectly straight and even, are placed at the distance of half an inch from each other at one of their ends, and three-tenths of an inch at the other. For greater convenience, the gauge is divided into two parts, and the two pieces are placed endways when required to be used. The length of this rule is divided into 240 equal parts, of which each represents one-tenth of an inch\*. To form the thermometer pieces, the earth is sifted with the greatest attention, after which it is mixed with water, and the paste thrust through an iron tube, which gives it a cylindrical form, to be cut afterwards into pieces of a proper size. When the pieces are dry, they must be presented to the gauge, where they ought to fit at the place of 0 on the scale. If by inadvertence of the workmen any piece penetrates to one or two degrees further, this degree is marked on its flat surface, and requires to be deducted when the piece is used in the

\* This is, in fact, the twelve-hundredth of an inch in the width according to the dimensions here given. T.



admeasurement of heat. The pieces thus adjusted are baked in a furnace to a red heat, to give them the consistence necessary for carriage. The heat employed in this part of the process is usually about six degrees, and the pieces are diminished more or less; but this is of no consequence when they come to be submitted to a superior degree of heat; and if it should happen that an inferior degree of heat is required to be measured, unbaked pieces are to be used, which are preserved in sheaths or cases to avoid friction.

When this pyrometer is to be used, one of the pieces is exposed in the fire-place whose heat is required to be determined; and when it has acquired the whole intensity, it is taken out, and suffered to cool, or for greater speed it is plunged in water; after which it is presented to the gauge, and its degree of contraction easily determined. Mr. Wedgwood has given us the result of several experiments made with his pyrometer, opposite to which he has placed the correspondent degrees of Fahrenheit.

	Pyrometer of Wedgwood.	Thermometer of Fahrenheit.
Red heat visible by the light	0	1077
Brass melts at	21	1857
Swedish copper melts at	27	4537
Pure silver melts at	28	4717
Pure gold melts at	32	5237
The heat of bars of iron raised to { small bar	90	12777
welding { large bar	95	13427
The greatest heat producible in a smith's forge	125	17327
Cast iron melts at	130	17977
The greatest heat of a wind furnace of eight inches square	160	21877

These various thermometers are not applicable to all cases. We cannot, for example, calculate with strictness the heat which escapes from living bodies, or determine with precision the temperature of any substance. But Messrs. De la Place and Lavoisier (Acad. des Sciences, 1780) have invented an apparatus which appears to leave nothing further to be desired. It is constructed upon the principle that ice absorbs all the heat communicated to it, without communicating it to other bodies until the whole

is melted; so that from hence we may calculate the degrees of heat communicated, by the quantity of ice which is melted. It was necessary, in order to afford strict results, to discover the means of causing the ice to absorb all the heat disengaged from the bodies under examination, and to cover it from the action of every other substance which might facilitate its fusion; and, lastly, to collect with great care the water produced by the fusion.

The apparatus constructed by these two celebrated academicians for this purpose, consists of three circular vessels nearly inscribed in each other; so that three capacities are produced. The interior space or capacity is formed by an iron grating, upon supports of the same metal. Here it is that the bodies subjected to experiment are placed. The upper part of this cavity is closed by means of a cover. The middle space, next to this, is designed to contain the ice which surrounds the interior compartment. This ice is supported and retained by a grate, upon which a cloth is spread. In proportion as the ice melts, the water flows through the grate and the cloth, and is collected in a vessel placed beneath. Lastly, the external space or compartment of the apparatus contains ice intended to prevent the effect of the external heat of the atmosphere.

To use this excellent machine, the middle or second space is filled with pounded ice, as is likewise the cover of the internal sphere; the same thing is done with regard to the external space, as well as to the general covering of the whole machine: the interior ice is suffered to drain; and, when it ceases to afford water, the covering of the internal space is raised, to introduce the body upon which the experiment is intended to be made. Immediately after this introduction, the covering is put on, and the whole apparatus remains untouched until the included body has acquired the temperature of 0, or the freezing temperature of water; which is the common temperature of the internal capacity. The quantity of water afforded by the melting of the ice is then weighed; and this is an accurate measure of the heat disengaged from the body, because the fusion of the ice is the effect of this heat only.

Experiments of this kind last fifteen, eighteen, or twenty hours.

It is of great consequence, that in this machine there should be no communication between the middle, or second, and the external space.

It is likewise necessary that the air of the apartment should not be lower than 0, because the interior ice would then receive a degree of cold lower than that temperature.

Specific heat is merely the proportional quantity of heat necessary to raise bodies of equal mass to the same number of degrees of temperature; so that, when the specific heat of a solid body is required, its temperature must be elevated a certain number of degrees, at which instant it must be placed in the internal sphere, and there left until its temperature is reduced to 0. The water is then collected, and this quantity divided by the product of the mass of the body; and the number of degrees of its original temperature above 0, will be proportional to its specific heat.

With regard to fluids, they are inclosed in vessels whose heat has been previously determined. The operation is then the same as for solids; excepting that the quantity of water afforded must be diminished by a deduction of that quantity which has been melted by the heat of the vessel.

If it be required to determine the heat which is disengaged during the combination of various substances, they must be all reduced, as well as their containing vessels, to the temperature of 0. The mixture must then be placed in the internal sphere; and the quantity of water collected is the measure of the disengaged heat.

In order to determine the heat of combustion and respiration, as the renewal of air is indispensable in these two operations, it is necessary to establish a communication between the internal part of the sphere and the surrounding atmosphere; and in order that the introduction of fresh air may not cause any perceptible error, these experiments ought to be made at a temperature little differing from 0, or at least the air which is introduced must previously be brought to this temperature.

To determine the specific heat of any gas, it is necessary to establish a current through the internal part of the sphere, and to place two thermometers, one at the place of introduction, and the other at the place of escape. By comparison of the temperatures exhibited by these two instruments, a judgment is formed of the heat absorbed, and the melted ice is measured.

An excellent memoir of Messrs. De la Place and Lavoisier may be consulted for the results of the experiments they have made. The present extract contains only a short account of their valuable labours.

The various means made use of for the admeasurement of heat, are founded on the general principle, that different bodies absorb heat in greater or less quantities. If this fact were not generally admitted, it might be established on the three following facts. Dr. Franklin having exposed two small pieces of cloth, of the same texture but of different colours, upon the surface of snow, perceived, a few hours afterwards, that the red cloth was buried in the snow, while the other which was white had not suffered any depression\*. M. de Saussure observes, that the peasants of the mountains of Switzerland are careful to spread a black earth over the surface of grounds covered with snow, when they are desirous of melting it, to sow their seed. So likewise children burn a black hat in the focus of a small lens which would scarcely heat a white one.

Such nearly are the phenomena of heat when it is disengaged in a state of liberty. Let us now contemplate those which it presents when it escapes from a state of combination.

Heat is sometimes disengaged in a state of simple mixture, as in the phenomena of vapours, sublimations, &c. If heat be applied to water, these two fluids will unite, and the mixture will be dissipated in the atmosphere; but it would be an abuse of words to call so weak an union by the name of combination: for, as soon as the heat becomes in a situation to combine with

\* They were exposed to the rays of the sun. T.



other bodies, it abandons the water, which returns to a liquid state. This body, during evaporation, continually carries with it a portion of heat; and hence, perhaps, result the advantages of transpiration, perspiration, &c.

But heat very frequently contracts a true chemical union with the bodies which it volatilizes: this combination is even so perfect, that the heat is not perceptible, but is neutralized by the body with which it is combined. It is then called latent heat, *calor latens*.

The several cases in which heat enters into combination, and passes to the state of latent heat, may be reduced to the two following principles:

The first principle.—Every body which passes from the solid to the liquid state, absorbs a portion of heat, which is no longer sensible to the thermometer, but exists in a true state of combination.

The academicians of Florence filled a vessel with pounded ice, and plunged a thermometer in it, which descended to 0. The vessel was then immersed in boiling water, and the thermometer did not rise during the whole time of the liquefaction of the ice. The fusion of ice therefore absorbs heat.

Mr. Wilcke poured a pound of water, heated to the 60th degree of Reaumur, upon a pound of ice. The melted mixture possessed the temperature of 0. Sixty degrees of heat had therefore entered into combination.

The Chevalier Laudriani has shewn that the fusion of metals, of sulphur, of phosphorus, of alum, of nitre, &c. absorb heat.

Cold is produced in the dissolution of all the (crystallized) salts.

Reaumur made a series of very interesting experiments on this subject, which confirm those of Boyle. Fahrenheit caused the thermometer to descend to forty degrees, by melting ice by strong nitrous acid. But the most astonishing experiments are those made by Messrs. Thomas Beddoes\*, physician, and Walker, apothecary at Oxford,

\* It does not appear that Dr. Beddoes either had or pretends to have any other share in the experiments of Mr. Walker, than that of having transmitted them to the Royal Society. T.

and inserted in the Philosophical Transactions for the year 1787†. The mixtures which produced the greatest degrees of cold are, 1. Eleven parts of muriate of ammoniac, or common sal ammoniac; ten parts of nitrate of potash, or common nitre; sixteen parts of sulphate of soda, or Glauber's salt; with thirty-two parts by weight of water: the two first salts should be dry, and in powder. 2. The nitric acid, muriate of ammoniac, and sulphate of soda, lowered the thermometer to eight degrees under 0. Mr. Walker has frozen mercury without using either ice or snow.

It is therefore an incontrovertible principle, that all bodies which pass from the solid to the liquid state, absorb heat, and retain it in so accurate a combination as to afford no sign of its presence. The heat is therefore fixed, neutralized, or latent.

The second principle.—All bodies, by passing from the solid or fluid state to the æriform state, absorb heat, which becomes latent; and it is by virtue of this heat that such bodies are placed and maintained in that state.

On this principle is founded the process used in China, India, Persia, and Egypt, to cool liquors used for drink.

The water intended for this purpose is put into very porous vessels, and exposed to the sun, or to a current of warm air, to cool the fluid contained within them.

It is by similar means that cool drink is obtained in the long journeys of the caravans. Interesting details on this subject may be seen in the Travels of Chardin, vol. iii. 1723; Tavernier's Voyages, vol. i. edit. 1738; Paul Lucas's Voyages, vol. ii. edit. 1724; and also in the *Mundus Subterraneus* of P. Kircher, lib. vi. sec. 2. cap. 2.

We may conclude from the experiments of Mr. Richmann, made in 1747, and inserted in the first volume of the imperial Academy of Petersburg, 1. That a thermometer taken out of water, and exposed to the air, always descends, even when its temperature is equal or superior to that of the water. 2. That it afterwards rises, until that it has acquired the temperature of the atmosphere.

† Also in the subsequent volumes.

3. That the time of descending is less than that which it employs to rise again. 4. That when the thermometer, withdrawn from the water, has arisen to the common temperature, its bulb is dry; but that it continues wet during the whole time of its standing beneath this common temperature.

To these consequences we will add others deduced from several curious experiments by the celebrated Cullen. 1. A thermometer suspended in the receiver of the air pump, descends two or three degrees during the time of exhaustion, and afterwards rises to the temperature of the vacuum. 2. A thermometer plunged in alcohol, in the receiver of the air pump, always descends, and the lower in proportion as the bubbles are stronger which issue from the alcohol; if it be withdrawn from this liquor, and suspended wet beneath the receiver, it falls eight or ten degrees while the air is pumping out.

It is well known that if the ball of a thermometer be wrapped in fine linen, and kept moist by sprinkling with ether, and the evaporation be facilitated by agitation in the air, the thermometer will descend to 0.

The immortal Franklin has proved, in his own person, that when the body perspires strongly, it is less heated than surrounding bodies, and that perspiration always produces a certain degree of coldness.—See his Letter to Dr. Lind.

The great number of labourers in the burning heats of our climate support themselves only by virtue of a copious perspiration, the fluid for which they replenish by drinking plentifully. The workmen employed in glass-houses, founderies, &c. often live in a medium hotter than their bodies, the natural temperature of which is equalized and moderated by perspiration.

If evaporation be increased by agitation of the air, the refrigeration is the greater. Hence the use of fans, ventilators, &c. which, though intended to give motion to warm air, afford likewise the virtue of cooling by facilitating and favouring evaporation.

Warm and dry air is best suited to form a refreshing current, because it is more calculated to dissolve and

absorb humidity; moist air is less proper, because it is already saturated.—Hence the necessity of frequently renewing the air to preserve the coolness of our apartments.

These principles have a nearer relation to medicine than is generally supposed. We find that almost all fevers end in perspirations, which, beside the advantage of expelling the morbid matter, possess likewise that of carrying off the matter of heat, and restoring the body to its common temperature. The physician who is desirous of moderating the excess of heat in the body of a patient, ought to maintain the air in that disposition which is most suitable to his views.

The use of volatile alkali is universally acknowledged to be of advantage in burns, the tooth-ach, &c. May not these effects be attributed to the volatility of this substance, which quickly combining with heat, carries it off, and leaves an impression of cold?—Ether is a sovereign remedy for the colic. Does not its virtue depend on the same principles?

The heat which has entered into combination with bodies during their transition from the solid to the liquid state, or from this last to the æriform state, may be again exhibited by causing these substances to return again to the states of liquefaction or solidity. In a word, every substance which passes from the liquid to the solid state, suffers its latent heat to escape, which at this instant becomes free or thermometrical heat.

The celebrated Fahrenheit, in the year 1724, having left water exposed to a colder temperature than that of ice, the water remained fluid: but it congealed by agitation; and the thermometer, which marked several degrees beneath the freezing point, suddenly rose to that temperature. Mr. Treiwald mentions a similar fact in the Transactions; and Mr. de Ratte made the same observation at Montpellier.

Mr. Baumé has shewn in his enquiries and experiments relating to several singular phenomena exhibited by water at the instant of its congelation, that several degrees of heat are always developed at that instant.



Gaseous substances are maintained in the aëriform state merely by the heat which is combined with them; and when to these substances, thus dissolved in caloric, another body is presented, to which they have a very strong affinity, they abandon their heat to unite with this last substance; and the caloric, thus expelled or disengaged, appears under the form of free or thermometrical heat. This disengagement of heat, by the concretion or fixation of gaseous substances, was observed by the celebrated Scheele, as may be seen in the valuable experiments which form the basis of his *Treatise on Air and Fire*. Since the time of this great man, rigorous calculations have been made of the quantity of latent heat existing in each of these gases: we are indebted to Messrs. Black, Crawford, Wilcke, De la Place, Lavoisier, &c. for many excellent researches on this subject.

## ARTICLE II.

### Concerning Light.

It appears that Light is transmitted to our eyes by a peculiar fluid which occupies the interval between us and visible bodies.

Does this fluid arrive directly from the Sun by successive emissions or eradiations? or is it a peculiar fluid distributed through space, and put in action by the Sun's rotary motion, or by any other cause? I shall not enter into any discussion upon this subject, but shall confine myself to point out the phenomena.

A. The motion of light is so rapid, that it passes through nearly eighty thousand leagues in a second.

B. The elasticity of the rays of light is such that the angle of reflection is equal to the angle of incidence.

C. The fluid of light is ponderous: for if a ray of light be received through a hole in a window-shutter, and the blade of a knife be presented to it, the ray is diverted from a light line, and is inflected towards the body. This circumstance shews that it obeys the law of attraction, and

sufficiently authorises us to class it among other bodies of this nature.

D. The great Newton succeeded in decomposing the solar light into seven primitive rays, which present themselves in the following order: red, orange, yellow, green, blue, indigo, violet. Dyes present us with only three colours, which are red, blue, and yellow; the combinations and proportions of these three principles form all the shades of colour with which the arts are enriched. Philosophers have maintained that among the solar rays there are three primitive colours.—See *Les Recherches de M. Marat*.

All natural bodies may be considered as prisms which decompose or rather divide the light. Some reflect the rays without producing any change and these are white; others absorb them all, and cause absolute blackness: the greater or less affinity of the several rays with various bodies, and perhaps likewise the disposition of the pores, is no doubt the cause that, when a pencil falls upon a body, some rays enter into combination, while others are reflected; and it is this which affords the diversity of colours, and the prodigious variety of shades under which bodies appear to our eyes.

We can no longer confine ourselves to consider light as a merely physical substance; the chemist perceives its influence in most of his operations, and finds it necessary to attend to its action, which modifies his results: and its effects are no less evident in the various phenomena of nature, than in the experiments performed in our laboratories.

We see that vegetation cannot take place without light. Plants deprived of this fluid become pale; and when in hot-houses the light comes to them from one part only, the vegetables incline towards the aperture, as if to shew the necessity of this beneficial fluid.

Without the influence of light, vegetables would exhibit but one lifeless colour; they are deprived of their beautiful shades by the interception of this luminous fluid. On these principles, celery, endive, and other plants, are bleached.

Vegetables are not only indebted to the light for their colour, but likewise for their smell, taste, combustibility, maturity, and the resinous principle, which equally depend upon this fluid. Hence it is, no doubt, that aromatic substances, resins, and volatile oils, are the inheritance of southern climates, where the light is more pure, constant, and intense.

We see, likewise, that the influence of light is evident in other beings : for, as Mr. Dorthes has observed, worms and grubs, which live in the earth or in wood, are of a whitish colour. The birds and flying insects of the night, are likewise distinguishable from those of the day by the want of brilliancy of colour ; and the difference is equally marked between those of the north and of the south.

A very astonishing property of light upon the vegetable kingdom is, that when vegetables are exposed to open day-light, or to the sun's rays, they emit vital air. We shall again attend to all these phenomena when we come to treat of the analysis of vegetables.

The fine experiments of Scheele and Berthollet have shewn that the absence or presence of light has an astonishing effect upon the result of chemical experiments. Light disengages vital air from several fluids, such as the nitric acid, the oxygenated marine acid, &c. It reduces the oxides or calces of gold, silver, &c. It changes the nature of oxygenated muriates, according to the observations of Mr. Berthollet. Light likewise determines the phenomena of vegetation exhibited by saline solutions, as I have shewn. From all which circumstances it is evident that we ought to attend to the effect of this agent in almost all our operations.

“ Organization, sensation, spontaneous motion, and life, exist only at the surface of the earth, and in places exposed to light : we might affirm that the flame of Prometheus's torch was the expression of a philosophical truth which did not escape the ancients. Without light, nature was lifeless, inanimate, and dead : a benevolent God, by producing light, has spread organization, sensation, and thought over the surface of the earth.”—*Elementary Treatise of Chemistry* by Mr. Lavoisier.

We ought not to confound the solar light with the light of our furnaces; the light of these has, as I am convinced, very evident effects in certain phenomena; but these effects are slow, and scarcely comparable with those of the solar light.

Although heat often accompanies light, the phenomena we have mentioned cannot be attributed to mere heat. Heat may indeed modify them where it exists, but most assuredly it cannot produce them.

## CHAPTER II.

### *Concerning Sulphur.*

WE are obliged to place Sulphur among the elements, though our predecessors pretended to have determined its constituent principles. This proceeding would appear to be retrograde, if it were not evident that the correction of mistakes is a real advancement in science.

The ancients used the word Sulphur to denote every combustible and inflammable substance. Accordingly we find, in all their writings, the expressions sulphur of metals, sulphur of animals, sulphur of vegetables, &c.

Stahl assigneth a determinate value to the denomination of Sulphur; and since the time of this celebrated chemist we have confined the name to denote a body of an orange-yellow colour, dry, brittle, capable of burning with a blue flame, and exhaling a penetrating odour during combustion: when rubbed, it becomes electric; and by a light pressure in the hand it cracks, and becomes reduced to powder.

It appears that sulphur is formed by the decomposition of vegetables and animals. It has been found on the walls of necessary-houses; and when the ditch of the



Porte St. Antoine, at Paris, was cleared, a considerable quantity was mixed with the decayed remains of vegetable and animal substances, that had filled the ancient ditches, and there putrefied.

Mr. Deyeux has likewise proved, that sulphur exists naturally in certain plants, such as *patientia*, *cochlearia*, &c. His processes for extracting it consist in—1. The washed root must be reduced by rasping into a fine pulp; this must be washed in cold water, and passed through a sieve or cloth of an open texture: the fluid passes in a turbid state, and deposits a precipitate, which when dried proves the existence of sulphur. 2. The pulp may be boiled, and the scum afforded by the ebullition afterwards dried: this scum contains sulphur. Several species of *rumex*, confounded under the name of *Patience*, do not contain sulphur. I have obtained it from the *rumex patientia* L, which grows on the mountains Cevennes, and is the same which is used at Paris. M. Le Veillard obtained sulphur by suffering vegetable substances to putrefy in well-water. Sulphur is abundantly contained in coal mines; it is found in combination with certain metals; it appears almost always where vegetable decomposition takes place; it forms the greater part of those pyritous and bituminous schists which occupy the focus of volcanos; it is sublimed in those places where the pyrites are decomposed; it is thrown out by subterraneous fires; and is found in greater or less quantities in volcanic districts. Much has been said concerning showers of sulphur; but it is at present well known that this error has chiefly arisen from the powder of the stamina of the pine, which is carried to great distances. Henckel saw the surface of a marsh entirely covered with this powder.

The known processes for extracting sulphur in the large way, and applying it to the purposes of commerce, consist in disengaging it from the pyrites or sulphures of copper, or of iron, by methods possessing various degrees of simplicity and economy. On this subject, the *Pyritology* of Henckel, Macquer's *Chemical Dictionary*, and the *Metallurgical Tracts* of Mr. Jars, may be consulted.

In Saxony and Bohemia the ores of sulphur are distilled in earthen tubes disposed in a gallery. The sulphur which is disengaged by the heat passes into receivers placed without, and in which care is taken to keep a sufficient quantity of water.

At Rammelsburg, at St. Bel, &c. large heaps of pyrites are made, which are decomposed by a gentle heat, at first applied to the mass from a stratum of combustible matter upon which it is placed. The heat is afterwards kept up by the action of the pyrites amongst each other. The sulphur which exhales cannot escape laterally, because care is taken to cover the sides with earth. It therefore rises to the summit of the truncated pyramid, where it is collected in small cavities made for that purpose. The heat of this part is sufficient to keep the sulphur in a fluid state; and it is taken out from time to time with ladles.

Almost all the sulphur used in France comes from the Solfatara. This volcanic country every where exhibits marks of the agency of subterraneous fire. The enormous masses of pyrites which are decomposed in the bowels of the earth produce heat, which sublimes part of the sulphur through apertures which the fire, and the effort of the vapours, have opened in all parts. The earths and stones which contain sulphur are distilled; and it is the result of this distillation which is called Crude Sulphur.

The crude sulphur is transported into France by the way of Marseilles, where it receives the necessary preparations to render it suitable to various purposes. 1. It is reduced into sticks or rolls, by fusing it, and pouring it into moulds: or, 2. It is formed into flowers of brimstone by subliming it with a gentle heat, and collecting this sulphureous vapour in a very close chamber of considerable extent. This very pure and finely divided sulphur is distinguished by the name of Flowers of Brimstone, or Sublimed Sulphur.

Sulphur enters into fusion by a moderate heat; and if the moment be seized in which the surface congeals, and the liquid sulphur contained beneath that surface be then poured out, the internal cavity will exhibit long needle-formed

crystals of an octahedral figure. This process, contrived by the famous Rouelle, has been applied to the crystallization of almost all the metals. Sulphur is found naturally crystallized in Italy, at Conilla near Cadiz, &c. Its usual form is octahedral; but I have, nevertheless, seen crystals of sulphur in perfect rhomboids.

Stahl thought that he had proved, by analysis and synthesis, that sulphur is formed by the combination of his phlogiston with the sulphuric acid. The happy series of proofs which he has left behind him for the establishment of his opinion, has appeared so complete, that, since the time of this great man, his doctrine has constantly been admitted as founded on absolute proof. This example was even urged as an instance to shew how high a degree of evidence the chemical analysis was capable of affording. But our discoveries respecting gaseous substances have shewn us, that the ancients were necessarily led into error for want of that knowledge. The immense researches of the moderns into the composition of acids, have shewn that these substances are decomposed in a variety of operations; and this revolution in the state of our knowledge must have produced a similar change in our methods of explaining the phenomena. An examination of the principal experiments of Stahl, upon which his doctrine essentially depends, will sufficiently shew the truth of what we have asserted.

If one third part of charcoal, and two thirds of sulphate of pot-ash, or vitriolated tartar, be mixed and fused in a crucible, the product is (liver of sulphur) sulphure of pot-ash. If this sulphure be dissolved in water, and the alkali be engaged by adding a few drops of sulphuric acid a precipitate is afforded, which consists of true sulphur: "whence," says Stahl, "the sulphur is a combination of phlogiston, or the inflammable principle of the charcoal with the sulphuric acid." The experiment was true, but the consequence is absurd; because it would follow that the sulphuric acid which was added, must have possessed the property of displacing sulphuric acid united to the alkali\*

\* Without pretending, on the present occasion, to dispute either for or against phlogiston, I shall observe that this argument is among

If Stahl had more strictly analysed the result or product of this operation, he would have been convinced that it does not contain a particle of sulphuric acid.

If he had been possessed of the power of operating in closed vessels, and of collecting the gaseous substances which are disengaged, he would have obtained a large quantity of carbonic acid, which arises from the combination of the oxigene of the sulphuric acid with the charcoal.

If he had exposed his liver of sulphur to the air in closed vessels, he would have seen that the vital air is absorbed, that the sulphure is decomposed, and that the sulphate of pot-ash, or vitriolated tartar is formed; which proves the recomposition of the sulphuric acid.

If charcoal be moistened with sulphuric acid or oil of vitriol, and then exposed to distillation, the products are carbonic acid or fixed air, sulphur, and much sulphureous or volatile vitriolic acid.

The experiments of Stahl exhibit the most perfect demonstration of the decomposition of the sulphuric acid into sulphur and oxigene; and it is not necessary, in the explanation of them, either to suppose the existence of an imaginary being, or to suppose that sulphur is a compounded body.

### CHAPTER III.

#### *Concerning Carbone.*

PURE charcoal is called Carbone in the new Nomenclature. This substance is placed among simple bodies, because no experiment has hitherto shewn the possibility of decomposing it.

the many paralogisms urged on both sides in this controversy. If there be any difficulty in conceiving how dephlogisticated sulphur, or pure vitriolic acid, may displace phlogisticated vitriolic acid, or sulphur, the same will apply to the opposite theory, which asserts that acrated sulphur, or vitriolic acid, displaces de-acrated vitriolic acid, or pure sulphur. T.



Carbone exists ready formed in vegetables. It may be cleared of all the volatile and oily principles by distillation; and, by subsequent washing in pure water, it may be deprived of all the salts which are mixed and confounded with it.

When it is required to procure carbone in a state of great purity it must be dried by strong ignition in a closed vessel: this precaution is necessary: for the last portions of water adhere with such avidity, that they are decomposed, and afford hydrogenous gas and carbonic acid.

Carbone exists likewise in the animal kingdom: it may be extracted by a process similar to that which we have described; but its quantity is small. It appears in the form of a light spongy mass, difficultly consumed in the air, and mixed with a great quantity of phosphates, and even of soda.

Carbone is likewise found in plumbago, of which it is one of the principles.

We shall treat more fully of this substance in the analysis of vegetables. But these concise ideas are sufficient to enable us to proceed in our account of its combinations, which is indeed the only object of the present short enumeration of its properties.

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## SECTION V.

Concerning Gases, or the Solution of certain Principles in Caloric, at the Temperature of the Atmosphere.

**C**ALORIC, in its combination with bodies, volatilizes some of them, and reduces them to the aëriform state. The permanence in this state in the temperature of the atmosphere constitutes the gases; so that, to reduce a substance to the state of gas, consists in dissolving it in caloric.

Caloric combines with various bodies, with greater or less facility; and we are acquainted with several that, at the temperature of the atmosphere, are constantly in the state of gas: there are others which pass to this state at some degrees higher, and these are called Volatile or Evaporable substances. They differ from fixed substances, because these last are not volatilized but by the application and combination of a strong dose of caloric.

It appears that all bodies do not indiscriminately require the same quantity of caloric to assume the gaseous state; and we shall see that this proportion may be deduced from the fixation and concretion of these gaseous substances.

To reduce any substance to the state of gas, the application of caloric may be made in various manners.

The more simple method consists in placing the body in contact with another body which is heated. In this situation, the heat on one hand diminishes the affinity of aggregation or composition, by separating the constituent principles to a greater distance from each other; on the other hand, the heat unites to the principles with which it has the strongest affinity, and volatilizes them. This process is according to the method of simple affinities; for it in fact consists of the exhibition of a third body, which, presented to a compound of several principles, combines with one of them, and carries it off.

The method of double affinity may likewise be used to convert any substance into the gaseous form; and this is what happens when we cause one body to act upon another to produce a combination, in which a disengagement of some gaseous principles take place. If I pour, for example, the sulphuric acid upon the oxide of manganese, the acid combines with the metal, while its caloric seizes the oxygen, and rises with it. This principle takes place not only in this instance, but on all other occasions wherein, an operation being performed without the application of heat, there is a production of vapour or gas.

The various states under which bodies present themselves to our eyes, depend almost entirely upon the different degrees of combination of caloric with those same bodies. Fluids do not differ from solids, but because

they constantly possess, at the temperature of the atmosphere, the dose of caloric which is requisite to maintain them in that state; they congeal and pass to the concrete state with greater or less facility, accordingly as the requisite quantity of caloric is more or less considerable.

All solid bodies are capable of passing to the gaseous state; and the only difference which exists between them in this respect is, that a dose of caloric is required for this purpose, which is governed—1. By the affinity of aggregation, which connects their principles, retains them, and opposes itself to a new combination. 2. By the weight of the constituent parts, which renders their volatilization more or less difficult. 3. By the agreement and attraction between the caloric and the solid body, which is more or less strong.

All bodies, whether solid or liquid, when they come to be volatilized by heat, appear in two states—that of vapour, or that of gas.

In the first case, these substances lose, in a short time, the caloric which raised them, and again appear in their original form the moment the caloric finds colder bodies to combine with; but it is rare that bodies thus divided resume their original consistence. This first state is that of vapour.

In the second case, the combination of caloric with the volatilized substance is such, that the ordinary temperature of the atmosphere is insufficient to overcome this union. This state constitutes the gases.

When the combination of caloric with any substance is such that a gas is produced, these invisible substances may be managed at pleasure, by the assistance of apparatus appropriated within our time to these uses. These apparatus are known by the name of Pneumato-chemic, Hydro-pneumatic apparatus, &c.

The pneumato-chemical apparatus, in general, consists of a wooden vessel, usually of a square form, and lined with lead or tin: two or three inches beneath the upper edge there is formed a groove, in which a wooden plank slides, having a hole in the middle, and a notch in one

of its sides; the hole is made in the centre of an excavation made in the shelf, of the figure of a funnel.

This vessel is filled with water or mercury, according to the nature of the gases operated upon. There are some which easily combine with water, and therefore require to be received over mercury.

The gases may be extracted in various manners.

When they are disengaged by fire, a recurved tube is adapted to the neck of the retort, one extremity of which is plunged in the water or the mercury of the pneumato-chemical vessel, and opens beneath the aperture in the shelf, which is in the form of a funnel. The junction of the tube with the neck of the retort is secured with the usual lute; a vessel filled with the liquid of the cistern is inverted upon the shelf over the aperture. When the gas is disengaged from the materials in the retort, it appears in the form of bubbles, which rise, and gain the superior part of the inverted vessel. When all the water is displaced, and the bottle is full of gas, it is withdrawn, by adapting a glass plate to its orifice to prevent its dissipation: it may then be poured from one vessel to another, and subjected to a variety of experiments to ascertain its nature.

When the gases are disengaged by means of acids, the mixture which is designed to afford them is put into a bottle with a recurved tube fitted to its neck; and this tube is plunged in the cistern in such a manner, that the bubbles of gas may pass, as in the former experiment, through the aperture of the funnel in the shelf.

The processes at present used to extract the gases, and to analyse them, are simple and commodious: and these processes have singularly contributed to our acquisition of the knowledge of these æriform substances, whose discovery has produced a revolution in chemistry.



## CHAPTER I.

*Concerning Hydrogenous Gas, or Inflammable Air.*

**I**NFLAMMABLE Air is one of the constituent parts of water; a circumstance which has entitled it to the denomination of Hydrogenous Gas. Its property of burning with vital air, has caused it to be distinguished by the name of Inflammable Air.

Hydrogenous gas has been procured long since. The famous philosophical candle attests the antiquity of this discovery; and the celebrated Hales obtained from most vegetables an air which took fire.

Hydrogenous gas may be extracted from all bodies in which it is a constituent part; but the purest is that afforded by the decomposition of water, and it is this fluid which usually affords it in our laboratories. For this purpose the sulphuric acid is poured upon iron, or zinc; the water, which serves as a vehicle for the acid, is decomposed on the metal; its oxigene combines with it, while the hydrogenous gas escapes. This explanation, however contrary to the ancient notion, is not the less a demonstrated truth; in fact, the metal exists in the state of an oxide in its solution by the sulphuric acid, as may be proved by precipitating it with pure vegetable alkali: on the other hand, the acid itself is not at all decomposed; so that the oxigenous gas cannot have been afforded to the iron but by the water. Water may be decomposed likewise still more directly by throwing it upon iron strongly heated; and hydrogenous gas may be obtained by causing water to pass through a tube of iron ignited to whiteness.

The hydrogenous gas may be extracted by the simple distillation of vegetables. Vegetable fermentation, and animal putrefaction, likewise produce this gaseous substance.

The properties of this gas are as follow:

A. Hydrogenous gas has a disagreeable, stinking odour. Mr. Kirwan has observed, that when it is extracted over mercury, it has scarcely any smell. It contains half its weight of water, and loses its smell the moment it is deprived of this additional substance.

Kirwan has likewise observed, that the volume of hydrogenous gas is one-eighth larger when received over water than when received over mercury.

These observations appear to prove, that the offensive smell of this gas arises only from the water it holds in solution.

B. Hydrogenous gas is not proper for respiration. The abbé Fontana assures us that he could not take more than three inspirations of this air: the count Morrozo has proved that animals perish in it in a quarter of a minute. On the other hand, several northern chemists have affirmed, in consequence of experiments made on themselves, that hydrogenous gas might be respired without danger; and it is some years since the unfortunate Pilatre du Rozier filled his lungs with it at Paris, and set it on fire during the expiration, which forms a very curious jet of flame. It was remarked to him, that the abbé Fontana had objected against the accuracy of the Swedish chemists. This intrepid philosopher answered the objection, by mixing one-ninth of atmospherical air with very pure hydrogenous gas. He respired this mixture, as usual; but when he attempted to set it on fire, the consequence was an explosion so dreadful, that he imagined all his teeth were blown out.

This opposition of opinions, and contradiction of experiments, respecting a phenomenon which seems capable of unanswerable decision by one single experiment, induced me to have recourse to trial, to fix my own ideas on the subject.

Birds, successively placed in a vessel of hydrogenous gas, died, without producing the smallest perceptible change in the gas itself.

Frogs placed in forty inches of hydrogenous gas died in the space of three hours and a half: while others lived fifty-five hours in oxygenous gas and atmospherical air; and

when I took them out still living, the air was neither vitiated nor diminished. Numerous experiments which I have made upon these animals, have led me to observe that they have the faculty of stopping their respiration, when placed in any noxious gas, to such a degree, that they inspire only once or twice, and afterwards suspend every function on the part of the respiratory organ.

I have since had occasion to observe that these animals are not reduced into a putrid mass by remaining in hydrogenous gas, as was affirmed some time ago. The fact which may have imposed on chemists who related this circumstance, is, that frogs are often enveloped in a mucus or sanies, which appears to cover them; but they exhibit the same phenomenon in all the gases.

After having tried the hydrogenous gas upon animals, I determined to respire it myself; and I found that the same volume of this air might be several times respired without danger. But I observed that this gas was not changed by these operations; whence I concluded that it is not respirable: for, if it were, it would suffer a change in the lungs, the object of respiration not being confined to the reception and emission of a fluid merely; it is a function much more noble, more interesting, more intimately connected with the animal œconomy: and we ought to consider the lungs as an organ which is nourished by the air, digests that which is presented to it, retains the beneficial, and rejects the noxious part. Since, therefore, inflammable air can be respired several successive times without danger to the individual, and without any alteration or change in itself, we may conclude indeed that inflammable air is not a poison, but that it cannot be considered as an air essentially proper to respiration. It is with hydrogenous gas in the lungs, as with those balls of moss and resin which certain animals swallow during the rigorous season of the winter. These balls are not digested, since the animals void them at the return of spring: but they delude hunger; and the membranes of the stomach are exercised upon them without danger, in the same manner as the lungs exert themselves upon the hydrogenous gas presented to them.

C. Hydrogenous gas is not combustible alone; it does not burn but by the concurrence of oxigene. If a vessel filled with this gas be reversed, and a lighted taper be presented to it, the hydrogenous gas is found to burn at the surface of the vessel; but the candle is extinguished the moment it is plunged lower. The most inflammable bodies, such as phosphorus, do not burn in an atmosphere of hydrogenous gas.

D. Hydrogenous gas is lighter than common air. One cubic foot of atmospheric air weighs seven hundred and twenty grains; a cubic foot of hydrogenous gas weighs seventy-two grains. The barometer being at 29' 9, and the thermometer 60° Fahrenheit, Mr. Kirwan found the weight of this air to that of common air as eighty-four to one thousand; consequently it was about twelve times as light.

Its specific gravity varies very much, because it is difficult to obtain it constantly of the same degree of purity. That which is extracted from vegetables contains the carbonic acid and oil, which increases its weight.

This levity of hydrogenous gas has caused certain philosophers to presume that it ought to arrive at and occupy the superior part of our atmosphere; and upon this supposition the most brilliant conjectures have been made respecting the influence which a stratum of this gas, predominating over the rest of the atmosphere, ought to produce in meteorology. They were not aware that this continual loss of matter is not agreeable to the wise œconomy of nature. They did not observe that this gas, during its ascent in the air, combines with other bodies, more especially the oxigene, and that water and other products are the result; the knowledge of which must necessarily lead us to that of most meteors.

The theory of balloons, or aërostatic machines, is founded on this levity of the hydrogenous gas.

In order that a balloon may rise in the atmosphere, it is sufficient that the weight of the balloon itself, and the air it incloses, should be less considerable than that of an equal bulk of atmospheric air; and it must rise till its weight is in equilibrio with an equal volume of the surrounding air.



The theory of the Mongolfiers is very different from this. In this case a given volume of atmospheric air is rarefied by heat, and kept separated from the common mass by a hollow vessel of cloth. This rarefied space may therefore be considered for a moment as consisting of a mass of air of greater levity, which must necessarily make an effort to rise in the atmosphere, and carry its covering along with it.

E. Hydrogenous gas exhibits various characters, according to its degree of purity, and the nature of the substances which are mixed with it.

It seldom happens that this gas is pure. That which is afforded by vegetables contains oil, and the carbonic acid. The inflammable air of marshes is mixed with a greater or less quantity of carbonic acid; and that which is afforded by the decomposition of pyrites sometimes holds sulphur in solution.

The colour of hydrogen, when set on fire, varies according to its mixtures. One-third of the air of the lungs, mixed with the inflammable air of pit-coal, affords a flame of a blue colour; inflammable air, mixed with nitrous air, affords a green colour; the vapour of either affords a white flame. The various mixtures of these gases, and the degree of compression to which they are subjected, when expressed out of an aperture in order to burn them, have, in the hands of certain operators, afforded very agreeable illuminations, well deserving the attention of learned and curious observers.

F. Hydrogenous gas possesses the property of dissolving sulphur. In this case it contracts a stinking smell, and forms hepatic gas.

Mr. Gengembre put sulphur into inverted vessels filled with hydrogenous gas, and dissolved it by means of the burning-glass. The hydrogenous gas, by this treatment, obtained all the characteristic properties of hepatic gas.

The formation of this gas is almost always an effect of the decomposition of water. In fact, the alkaline sulphures, or livers of sulphur, do not emit any disagreeable smell while they are dry; but the moment they are

moistened, an abominable smell is perceived, and sulphate of pot-ash, or vitriolated tartar, begins to be formed. These phenomena prove that the water is decomposed; that one of its principles unites to the sulphur, and volatilizes it; while the other combines with the alkali, and forms a more fixed product.

Sulphurated hydrogenous gas may be obtained by dissolving the sulphures or hepars by acids. Those acids in which the oxygen is most adherent disengage the greatest quantity. The muriatic acid produces twice as much as the sulphuric. That which is produced by this last, burns with a blue flame; but that which is disengaged by the muriatic acid, burns with a yellowish white flame.

Scheele has taught us the means of obtaining this gas in great abundance, by decomposing artificial pyrites, formed by three parts of iron and one of sulphur, to which spirit of vitriol is added.

The natural decomposition of pyrites in the bowels of the earth produces this gas; which escapes with certain waters, and communicates peculiar virtues to them.

The most general properties of these gases are:

1. They render the white metals black.
2. They are improper for respiration.
3. They impart a green colour to syrup of violets.
4. They burn with a light blue flame, and deposit sulphur by this combustion.

5. They mix with the oxygenous gas of the atmospheric air, and form water; at the same time that the sulphur, before held in solution, falls down. Hence it happens that sulphur is found in the channels of hepatic waters, though their analysis does not shew the existence of an atom of that substance held in solution.

6. They impregnate water, and are sparingly soluble in that fluid; but heat or agitation dissipates them again.

The air which burns at the surface of certain springs, and forms what is known by the name of burning springs, consists of hydrogenous gas holding phosphorus in solution. It smells like putrid fish. The Pere Lami has discovered

one of these springs in the isles of St. Colombat. Dauphiny exhibits another similar spring at the distance of four leagues from Grenoble. The ignes fatui which glide along burying-grounds, and which the superstitious people suppose to consist of the spirits of the departed, are phenomena of this nature, which we shall speak of when we come to treat of phosphorus.

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## CHAPTER II.

*Concerning Oxygenous Gas, or Vital Air.*

THIS gaseous substance was discovered by the celebrated Priestley, on the 1st of August 1774. Since that memorable day, means have been devised of obtaining it from various substances; and its properties have shewn that it is a production of the most interesting nature in the knowledge of chemistry.

No part of the atmosphere exhibits vital air in its greatest degree of purity. It is always combined, mixed, or altered by other substances.

But this air, which is the most general agent in the operations of nature, exists in combination with various substances; and it is by their decomposition that it may be extracted and procured.

A metal exposed to the air becomes changed; and these changes are produced only by the combination of the pure air with the metal itself. Simple distillation of some of these metals thus changed, or oxides, is sufficient to disengage this vital air; and it is then obtained in a very pure state, by receiving it in the hydro-pneumatic apparatus. One ounce of red precipitate affords about a pint.

All acids have vital air for their base: there are some which yield it easily. The distillation of nitre decomposes

the nitric acid; and about twelve hundred cubic inches of oxygenous gas are obtained from a pound of this salt.

The nitric acid, when distilled from various substances, is decomposed, and its constituent parts may be obtained separately.

Messrs. Priestley, Ingenhousz, and Sennebier discovered nearly at the same time that vegetables exposed to the light of the sun emit vital air. We shall elsewhere speak of the circumstances of these phenomena; but shall at present confine ourselves to the observation, that the emission of vital air is proportioned to the vigour of the plant, and the vivacity of the light; and that the direct emission of the rays of the sun is not necessary to produce this gaseous dew; it is sufficient that the plant be well enlightened, in order that it may transpire pure air: for I have often collected it in abundance from a kind of moss which covers the bottom of a vessel filled with water, and so well defended that the sun never shone directly upon it.

In order to procure the vital air which is disengaged from plants, it is sufficient to inclose them beneath a glass vessel filled with water, and inverted over a tub filled with the same fluid. The moment the plant is acted on by the sun, small bubbles of air are formed on its leaves, which detaching themselves, rise to the upper part of the vessel, and displace the liquid.

This dew of vital air is a beneficial gift of nature, to repair incessantly the consumption of vital air. The plant absorbs atmospherical mephitic, and emits vital air. Man, on the contrary, is kept alive by vital air, and emits much mephitic. It appears therefore that the animal and vegetable kingdoms labour for each other; and that by this admirable reciprocity of service the atmosphere is continually repaired, and an equilibrium maintained between its constituent principles.

The influence of solar light is not confined to the production of vital air by its action upon vegetables alone; it has likewise the singular property of decomposing certain substances, and disengaging this gas.

A bottle of oxygenated muriatic acid, exposed to the sun, suffers all the superabundant oxygen which it contained



to escape, and passes to the state of ordinary muriatic acid. The same acid, exposed to the sun in a bottle wrapped in black paper, does not suffer any change; and, when heated in a dark place, is even reducible into gas without decomposition. The nitric acid likewise affords oxygenous gas, when exposed to the sun; whereas heat alone volatilizes it without decomposition.

The muriate, or marine salt of silver, placed under water, and exposed to the sun, suffers oxygenous gas to escape from it. I have observed that red precipitate likewise affords oxygen in similar cases, and that it becomes black in no very long space of time.

We may likewise obtain oxygenous gas by disengaging it from its bases by means of the sulphuric acid. The process to which I give the preference, on account of its simplicity, is the following:—I take a small apothecary's phial, into which I put one or two ounces of manganese, and pour thereon a sufficient quantity of sulphuric acid to form a liquid paste. I afterwards fit a cork to the opening of the bottle, with a hole through it, into which is inserted a recurved tube; one of whose extremities enters the bottle, while the other is placed under the shelf of the pneumatological apparatus. When the apparatus is thus disposed, I present a small coal to the lower part of the bottle, and oxygenous gas is immediately disengaged.

The manganese I use was discovered by me at St. Jean de Gardonnenque. It affords its oxygen with such facility, that nothing more is necessary for this purpose than to incorporate it with the sulphuric acid. This gas is not perceptibly mixed with nitrogenous gas (or phlogisticated air); and the first bubble is as pure as the last.

Oxygenous gas exhibits certain properties, according to its degree of purity. These depend in general upon the substances which afford it. That which is obtained from the mercurial oxides almost always holds a small quantity of mercury in solution: I have been a witness to its having produced a speedy salivation on two persons who used it for disorders of the lungs. In consequence of these observations, I filled bottles with this gas, exposed them to an intense cold, and the sides became obscured with a stratum

of mercurial oxide, in a state of extreme division. I have several times heated the bath, over which I caused this gas to pass; and I obtained, at two different times, a yellow precipitate in the bottle in which I had received the gas.

The oxygenous gas extracted from plants is not equally pure with that afforded by the metallic oxides: but from whatever substances it is obtained, its general properties are the following:

A. It is more ponderous than the air of the atmosphere; the cubic foot of atmospherical air weighing seven hundred and twenty grains, while the cubic foot of pure air weighs seven hundred and sixty-five. According to Mr. Kirwan, its weight is to that of common air as eleven hundred and three to one thousand. One hundred and sixteen inches of this air weighed 39,09 grains; one hundred and sixteen inches of common air weighed 35,38 grains at the temperature of ten degrees of Reaumur, and twenty-eight inches of pressure. One hundred parts of common air weighed forty-six, and one hundred parts of vital air fifty.

B. Oxygenous gas is the only fluid proper for combustion. This acknowledged truth caused the celebrated Scheele to give it the name of Air of Fire.

To proceed with greater order in the examination of one of the most important properties of oxygenous gas, since it belongs exclusively to this fluid, we shall lay down the four following principles, as incontestable results of all the known facts.

The first principle.—Combustion never takes place without vital air.

The second principle.—In every combustion there is an absorption of vital air.

The third principle.—There is an augmentation of weight in the products of combustion equal to the weight of the vital air absorbed.

The fourth principle.—In all combustion there is a disengagement of heat and light.

I. The first of these propositions is a strict truth. Hydrogenous gas does not burn alone, without the assistance of oxygen; and all combustion ceases the moment that oxygenous gas is wanting.

II. The second principle contains a truth no less general. If certain bodies, such as phosphorus, sulphur, &c. be burned in very pure oxygenous gas, this is absorbed to the last particle; and when the combustion is effected in a mixture of several gases, the oxygen alone is absorbed, and the others remain unchanged.

In the slower combustions, such as the rancidity of oils, and the oxidation of metals, there is equally an absorption of oxygen, as may be shewn by confining these bodies in a determinate mass of air.

III. The third principle, though not less true than the preceding, requires more explanation; and for this purpose we shall distinguish those combustions whose result, residue, and product are fixed, from those which afford volatile and fugacious substances. In the first case the oxygenous gas quietly combines with the body; and by weighing the same body the moment the combustion has completely taken place, it is easily ascertained whether the increase in weight be proportioned to the oxygen absorbed. This happens in all the cases wherein the metals are oxidized, or oils rendered rancid; and in the production of certain acids, such as the phosphoric, the sulphuric, &c. In the second case, it is more difficult to weigh all the results of the combustion, and consequently to ascertain whether the augmentation in weight be proportioned to the quantity of the air absorbed. Nevertheless, if the combustion be made in inverted vessels, and the whole of the products be collected, it is found that their augmentation in weight is strictly equal to that of the air absorbed.

IV. The fourth principle is that whose applications are the most interesting to be known.

In most combustions, the oxygenous gas becomes fixed and concrete. It therefore abandons the caloric which maintained it in the æriform state; and this caloric being set at liberty, produces heat, and endeavours to combine itself with the substances nearest at hand.

The disengagement of heat is therefore a constant effect in all the cases wherein vital air is fixed in bodies; and it follows, from this principle—1. That heat is most eminently resident in the oxygenous gas which maintains

combustion. 2. That the more oxigene is absorbed in a given time, the stronger will be the heat. 3. That the only method of producing a violent heat consists in burning bodies in the purest air. 4. That fire and heat must be more intense in proportion as the air is more condensed. 5. That currents of air are necessary to maintain and expedite combustion. It is upon this principle that the theory of the effects of the cylinder lamps is founded : the current of air, which is renewed through the tube, supplies fresh air every instant ; and by continually applying a new quantity of oxygenous gas to the flame, a heat is produced sufficient to ignite and destroy the smoke.

It is likewise on the same principle that we explain the great difference that exists between heat produced by a slow combustion, and that which is afforded by rapid combustion. In the latter case the same quantity of heat and light is produced in a second, which might have been produced in the other case in a much longer time.

The phenomena of combustion, by means of oxygenous gas, depend likewise upon the same laws. Professor Lichtenberger, of Gottingen, soldered the blade of a knife to a watch spring by means of oxygenous gas ; Messrs. Lavoisier and Erhmann have subjected almost all the known bodies to the action of fire maintained by oxygenous gas alone ; and they produced effects which the burning-glass could not have operated.

Mr. Ingenhoufz has shewn us, that if an iron wire be bent into a spiral form, and any combustible substance whatever be fixed to one of its ends, and set on fire, the wire will itself be fused by plunging it into oxygenous gas.

Mr. Forster, of Gottingen, found that the light of glow-worms is so beautiful and bright in oxygenous gas, that one single insect was sufficient to afford light to read the *Annales Savantes* of Gottingen, printed in a very small character. Nothing more is wanting therefore than to apply this air to combustion with facility and œconomy ; and Mr. Meusnier has succeeded in this, by constructing a simple and commodious apparatus. On



this subject the treatise of Mr. Erhmann upon fusion may be consulted.

The description of the gazometer may likewise be seen in the *Elementary Treatise of Chemistry*, by Mr. Lavoisier.

We shall distinguish three states in the very act of combustion—ignition, inflammation, and detonation.

Ignition takes place when the combustible body is not in the *aëriform* state, nor susceptible of assuming that state by the simple heat of combustion. This happens when well-made charcoal is burned.

When the combustible body is presented to oxygenous gas, in the form of vapour or gas, the result is flame; and the flame is more considerable, in proportion as the combustible body is more volatile. The flame of a candle is not kept up but by the volatilization of the wax, which is continually effected by the heat of the combustion.

Detonation is a speedy and rapid inflammation, which occasions a noise by the instantaneous formation of a vacuum. Most detonations are produced by the mixture of hydrogenous and oxygenous gas, as I have shewn in my *Memoir upon Detonations*, in the year 1781. It has been since proved, that the product of the rapid combustion of these two gases is water. Very strong detonations may be produced by burning a mixture of one part of oxygenous gas with two of hydrogen. The effect may be rendered still more terrible, by causing the mixture to pass through soap-water, and setting fire to the bubbles which are heaped on the surface of the fluid.

Chemistry presents several cases in which the detonation arises from the sudden formation of some gaseous substances, such as that which is produced by the inflammation of gunpowder; for in this case there is a sudden production of carbonic acid, of nitrogen gas, &c. The production or instantaneous creation of any gas whatever, must occasion a shock or agitation in the atmosphere, which necessarily affords an explosion; the effect of these explosions increases, and becomes stronger, from the opposition of any obstacles against the escape of the gas.

C. Oxygenous gas is the only gas proper for respiration. It is the most eminent property which has entitled it to the name of Vital Air; and we shall give the preference to this denomination in the present article.

It has long since been known that animals cannot live without the assistance of air. But the phenomena of respiration have been very imperfectly known until lately.

Of all the authors who have written concerning respiration, the ancients are those who have had the most accurate ideas of it. They admitted in the air a principle proper to nourish and support life, which they denoted by the name of *pabulum vite*; and Hippocrates expressly says, *spiritus etiam alimentum est*. This idea, which was connected with no hypothesis, has been successively replaced by systems void of all foundation. Sometimes the air has been considered as a stimulus in the lungs, which kept up the circulation by its continual action. Vide Haller.— Sometimes the lungs have been considered as bellows designed to cool the body, heated by a thousand imaginary causes: and when it was proved that the volume of air was diminished in the lungs, it was thought to be an explanation of every difficulty, to say that the air was deprived of its spring.

At this day, however, we are enabled to throw some light on one of the most important functions of the human body. in order to proceed with more perspicuity, we shall reduce our notions to several principles.

1. No animal can live without the assistance of air. This fact is universally admitted; but it has not been known until lately that the faculty which the air possesses of answering the purpose of respiration, arises only from one of the principles of atmospheric air, known by the name of vital air.

2. All animals do not require the same purity in the air. Birds, as well as men, and the greatest part of quadrupeds, require a very pure air; but those which live in the earth, or which hide themselves in a state of stupefaction during the winter, can subsist by means of a less pure air.

3. The manner of respiring the air is different in the several subjects. In general, nature has given to animals an organ, which by its involuntary dilatation and contraction receives and expels the fluid in which the animal moves and exists. This organ is more or less perfect, more or less concealed and defended from external injury, according to its importance, and influence upon the life of the creature, as Mr. Broussonnet has observed.

Amphibious animals respire by means of lungs: but they can suspend their motion even whilst they are in the air; as I have observed with regard to frogs, which stop their respiration at pleasure.

The manner of respiration in fishes is very different; these animals come from time to time to inhale the air at the surface of the water, where they fill their vesicle, and digest it afterwards at their ease. I have for a long time observed the phenomena of fishes in the act of respiration; and am well assured that they are sensible of the action of all the gases, like other animals. Mr. De Fourcroy has observed that the air contained in the vesicle of the carp is nitrogene gas (phlogisticated air).

Insects with tracheæ exhibit organs still more remote from ours in their construction. In these animals, respiration is effected by the tracheæ distributed along the body. They accompany all the vessels, and terminate by losing themselves in insensible pores at the surface of the skin.

These insects appear to me to exhibit several very evident points of analogy with vegetables.

1. Their respiratory organs are formed in the same manner, being disposed through the whole body of the vegetable and the animal.—2. Insects do not require a great degree of purity in the air; and plants are nourished with atmospherical mephitis.—3. Both the one and the other transpire vital air. The abbé Fontana discovered several insects in stagnant waters, which, when exposed to the sun afforded vital air: and the green matter which is formed in stagnant waters, and is by Dr. Priestley placed among the *confervæ*, in conformity with the opinion of his friend Mr. Bewley—which Mr. Senebier has supposed to be the *conserva cespitosa filis rectis undique divergentibus*

*Halleri*, and which has appeared to Dr. Ingenhoufz to be nothing else but a mass of animalcula—affords a prodigious quantity of this air when exposed to the sun.—4. Insects likewise afford, by chemical analysis, principles similar to those of plants, such as resins, volatile oils, &c.

Father Vaniere appears to have known, and very elegantly expressed, the property of vegetables to support themselves by means of vital air:

. . . . . Arbor enim (res non ignota), ferarum  
Instar et halituum, piscisque latentis in imo  
Gargite, vitales et reddit et accipit auras.

PROEIDIUM RUSTICUM, l. vi.

Animals with lungs respire only by virtue of the vital air which surrounds them. Any gas deprived of this mixture becomes immediately improper for respiration; and this function is exercised with so much the greater liberty, as vital air exists in a greater proportion in the air respired.

Count Morozzo placed successively several full-grown sparrows under a glass bell, inverted over water. It was at first filled with atmospherical air, and afterwards with vital air. He observed—

1. In atmospherical air,	Hours.	Min.
The first sparrow lived	3	0
The second - - -	0	3
The third . . .	0	1

The water rose in the vessel eight lines during the life of the first; four during the life of the second; and the third produced no absorption.

2. In vital air,	Hours.	Min.
The first sparrow lived	5	23
The second - - -	2	10
The third - - -	1	30
The fourth - - -	1	10
The fifth - - -	0	30
The sixth - - -	0	47
The seventh - - -	0	27
The eighth - - -	0	30
The ninth - - -	0	22
The tenth - - -	0	21



From these experiments it may be concluded, 1. That an animal lives longer in vital air than in atmospherical air. 2. That an animal can live in air in which another has died. 3. That, independent of the nature of the air, respect must be had to the constitution of the animals, as the sixth lived forty-seven minutes, and the fifth only thirty. 4. That there is either an absorption of air, or the production of a new kind of air, which is absorbed by the water as it rises.

It remains, at present, to examine what are the changes produced by respiration. 1. In the air. 2. In the blood.

The gas emitted by expiration is a mixture of nitrogene gas, carbonic acid, and vital air. If the air which issues from the lungs be made to pass through lime-water, it renders it turbid; if it be received through tincture of turnsole, it reddens it; and if a pure alkali be substituted instead of the tincture of turnsole, it becomes effervescent.

When the carbonic acid has been absorbed by the foregoing process, the remainder of this air consists of nitrogene gas and vital air. The vital air is shewn to be present by means of nitrous air. The air in which I had caused five sparrows to perish, afforded seventeen hundredth parts of vital air. After having thus deprived the expired air of all its vital air, and all its carbonic acid, the remainder is nitrogene gas.

It has been observed that frugivorous animals vitiate the air less than carnivorous animals.

A portion of the air is absorbed in respiration. Borelli formerly took notice of this; and Dr. Jurin had calculated that a man inspired forty cubic inches of air in his usual inhalations, and that in the greatest he could receive two hundred and twenty inches; but that a portion was always absorbed. The celebrated Dr. Hales endeavoured to determine this absorption more strictly, and he estimated it at a sixty-eighth of the total of the respired air; but he did not consider it as more than a hundred and thirty-sixth, on account of errors which he supposed to have taken place. Now a man respire twenty times in a minute, and inhales forty cubic inches of air at each inspiration: this makes forty-eight thousand per hour; which, divided by

one hundred and thirty-six, gives about three hundred and fifty-three inches of air absorbed and destroyed in the hour. The process of Hales is not exact; because he passed the air expired through water, which must have retained a sensible proportion.

From more accurate experiments, Mr. De la Metherie has proved, that three hundred and sixty cubic inches of vital air are absorbed in an hour.

My experiments have not shewn near so great a loss.

This fact affords a proof of the facility with which air is vitiated by respiration when it is not renewed, and shews why the air of theatres is in general so unwholesome.

II. The first effect which the air appears to produce upon the blood is, that of giving it a vermilion-colour. If the blackish venous blood be exposed in a pure atmosphere, it becomes of a vermilion-colour at its surface: this fact is daily observed when blood is suffered to remain exposed in a porringer to the air. Air which has remained in contact with blood extinguishes candles, and precipitates lime-water. Air injected into a determinate portion of a vein between two ligatures, renders the blood of a higher colour, according to the fine experiments of Dr. Hewson.

The blood which returns from the lungs is of a higher colour, according, to the observations of Messrs. Cigna, Hewson, &c. Hence arises the great intensity of the colour of arterial blood, compared with venous blood.

Mr. Thouvenel has proved, that by withdrawing the air which is in contact with the blood, it may be again made to lose its colour.

Mr. Beccaria exposed blood in a vacuum, where it remained black, but assumed the most beautiful vermilion-colour as soon as it was again exposed to the air. Mr. Cigna covered blood with oil, and it preserved its black colour.

Dr. Priestley caused the blood of a sheep to pass successively into vital air, common air, mephitic air, &c. and he found that the blackest parts assumed a red colour in respirable air, and that the intensity of this colour was in proportion to the quantity of vital air present. The same philosopher filled a bladder with blood, and exposed it to

pure air. That portion of blood which touched the surface of the bladder, became red, while the internal part remained black; an absorption of air therefore took place through the bladder, in the same manner as when the contact is immediate.

All these facts incontestably prove, that the vermilion-colour assumed by the blood in the lungs, is owing to the pure air which combines with it.

The vermilion-colour of blood is therefore the first effect of the contact, absorption, and combination of pure air with the blood.

The second effect of respiration is to establish a real focus of heat in the lungs; which is a circumstance very opposite to the precarious and ridiculous notion of those who have considered the lungs as a kind of bellows designed to cool the human body.

Two celebrated physicians, Hales and Boerhaave, have observed that the blood acquired heat in passing through the lungs; and modern physiologists have estimated this augmentation of heat at eleven hundredths.

The heat in each class of individual animals is proportioned to the magnitude of their lungs, according to Messrs. De Buffon and Broussonet.

Animals with cold blood have only one auricle and one ventricle, as Aristotle observed.

Persons who have respired vital air, agree in affirming that they perceived a gentle heat vivifying the lungs, and insensibly extending from the breast into all the other parts of the body.

Ancient and modern facts unite therefore to prove, that a focus of heat really exists in the lungs, and that it is maintained and kept up by the air of respiration. We are able, at present, to explain all these phenomena. In fact there is an absorption of vital air in respiration. Respiration then may be considered as an operation by means of which vital air passes continually from the gaseous to the concrete state: it must therefore at each instant abandon the heat which held it in solution, and in the state of gas. This heat produced at every inspiration must be proportioned to the volume of the lungs, to the activity of

this organ; to the purity of the air, the rapidity of the inspirations, &c. Hence it follows that, during the winter, the heat produced must be more considerable, because the air is more condensed, and exhibits more vital air under the same volume. By the same reason, respiration ought to produce more heat in the inhabitants of northern climates; and this is one of the causes prepared by nature to temperate, and continually balance, the extreme cold of these climates. It follows likewise that the lungs of asthmatic persons are less capable of digesting the air; and I am assured that they emit the air without vitiating it: from which cause their complexion is cold, and their lungs continually languishing; vital air is therefore wonderfully comfortable to them. It may be easily conceived from these principles why the heat of animals is proportioned to the volume of their lungs; and why those which have only one auricle, and one ventricle, have cold blood, &c.

The phenomena of respiration are therefore the same as those of combustion.

Vital air, by combining with the blood, forms the carbonic acid, which may be considered as antiputrescent as long as it remains in the circulation; and that it is afterwards emitted through the pores of the skin, according to the experiments of the count De Milly, and the observations of Mr. Fouquet.

Vital air has been used with success in certain disorders of the human body. The observations of Mr. Caillens are well known. He caused persons affected with phthical disorders to respire it with the greatest success. I have myself been a witness to the most wonderful effects of this air in a similar case. Mr. De B——— was in the last stage of a confirmed phthisis. Extreme weakness, profuse sweats, a flux of the belly, and in short every symptom announced the approach of death. One of my friends, Mr. De P——, put him on a course of vital air. The patient respired it with delight, and asked for it with all the eagerness of an infant at her breast. During the time that he respired it he felt a comfortable heat, which distributed itself through all his limbs. His strength



increased with the greatest rapidity; and in six weeks he was able to take long walks. This state of health lasted for six months: but after this interval he relapsed; and being no longer able to have recourse to the use of vital air, because Mr. De P——— had departed for Paris, he died.—I am very far from being of opinion that the respiration of vital air ought to be considered as a specific, in cases of this nature. I am even in doubt whether this powerful air is perfectly adapted to such circumstances; but it inspires cheerfulness renders the patient happy, and in desperate cases it is most certainly a precious remedy, which can spread flowers on the borders of the tomb, and prepare us in the gentlest manner for the last dreadful effort of nature.

The absolute necessity of vital air in respiration, enables us to lay down positive principles for purifying the corrupted air of any given place. This may be done in three ways. The first consists in correcting the vitiated air by means of substances which are capable of seizing the noxious principles. The second consists in displacing the corrupted air, and substituting fresh air in the room of it; as is done by means of ventilators, the agitation of doors, &c. And the third consists in pouring into the mephitised atmosphere a new quantity of vital air.

The processes employed in purifying corrupted air, are not all certain in their effects. The fires which are lighted for this purpose have no other advantage than to establish ascending currents, and to burn unhealthy exhalations; and perfumes do nothing more than disguise the bad smell, without changing the nature of the air, as the experiments of Mr. Achard shew.

## CHAPTER III.

*Concerning Nitrogene Gas, Azote, or Atmospherical Mephitis,*

IT has been long since ascertained, that air which has served the purposes of combustion and respiration, is no longer proper for those uses: the air thus corrupted has been distinguished by the names of Phlogisticated Air, Mephitised Air, Atmospherical Mephitis, &c. I call it Nitrogene Gas, for the reasons explained in the preliminary discourse.

But this residue of combustion or respiration is always mixed with a small quantity of vital air and carbonic acid, which must be removed in order to have the nitrogene gas in a state of purity. There are several methods which may be used to obtain nitrogene gas, in a very pure state.

1: Scheele has taught us, that by exposing sulphure of alkali, or liver of sulphur, in a vessel filled with atmospherical air, the vital air is absorbed; and, when the absorption is complete, the nitrogene gas remains pure.

By exposing, in atmospheric air over mercury, a mixture of iron and sulphur, kneaded together with water, Mr. Kirwan obtained nitrogene gas so pure, that it suffered no diminution by nitrous gas. He deprived it of all humidity, by successively introducing dried blotting-paper into the vessel which contained it. Care must be taken to withdraw this air in time from the paste which affords it; otherwise it will be mixed with hydrogen or inflammable gas, which is afterwards disengaged. 2. When by any means, such as the oxidation of metals, the rancidity of oils, the combustion of phosphorus, &c. the vital air of the atmosphere is absorbed, the residue is nitrogene gas. All these processes afford methods of greater or less accuracy to determine the proportions of vital air and nitrogene gas in the composition of the atmosphere.

3. This mephitic may likewise be procured by treating muscular flesh, or the well-washed fibrous part of blood, with nitric acid in the hydro-pneumatic apparatus. But it must be carefully observed that these animal matters ought to be fresh; for, if they have begun to be changed by the putrid fermentation, they afford carbonic acid mixed with hydrogen gas.

A. This gas is improper for respiration and combustion.

B. Plants live in this air, and freely vegetate in it.

C. This gas mixes with the other airs, without combining with them.

D. It is lighter than the atmospheric air, the barometer standing at 30. 46, and Fahrenheit's thermometer at 60: the weight of nitrogene gas is to that of common air as nine hundred and eighty-five to one thousand.

E. Mixed with vital air, in the proportion of 72 to 28, it constitutes our atmosphere. The other principles which analysis exhibits in the atmosphere, are only accidental, and by no means necessary.

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## SECTION VI.

Concerning the Mixture of Nitrogene and Oxigene Gas; or of Atmospheric Air.

THE gaseous substances we have treated of seldom exists alone and insulated; nature presents them every where to our observation in a state of mixture or of combination. In the first case these gases preserve the aëriiform state; in the second they for the most part form fixed and solid bodies. Nature, in its several decompositions, reduces almost all the principles of bodies into gas. These new substances unite together, combine, and from thence result compounds of considerable simplicity in their principles, but which become complicated by subsequent mixtures

and combinations. We may follow the operations of nature, step by step, without departing from the plan we have adopted.

The mixture of about seventy-two parts of nitrogene gas, and twenty-eight of oxigene, form this fluid mass in which we live. These two principles are so well mixed, and each of them is so necessary to the support of the various functions of individuals which live or vegetate upon the globe, that they have not yet been found separate and alone.

The proportion of these two gases is subject to variation in the mixture which forms the atmosphere: but this difference depends only upon local causes; and the most usual proportion is that which we have here mentioned.

The characteristic properties of vital air are modified by those of nitrogene gas, and these modifications even seem to be necessary: for if we were to respire vital air in its state of purity, it would quickly consume our life; and this virgin air is no more suitable to our existence than distilled water. Nature does not appear to have designed us for the use of these principles in their greatest degree of perfection.

The atmospheric air is elevated several leagues above our heads, and fills the deepest subterraneous cavities. It is invisible, insipid, inodorous, ponderous, elastic, &c. It was the only gaseous substance known before the present epocha of chemistry; and the infinite gradations of all the invisible fluids which presented themselves so frequently to the observation of philosophers, were always attributed to modifications of the air. Almost the whole of what has been written upon the air relates only to its physical properties. We shall confine ourselves to point out the chief of these.

A. Air is a fluid of extreme rarefaction, obedient to the smallest motion: the slightest percussion deranges it; and its equilibrium, which is continually destroyed, is continually endeavouring to restore itself.

Though very fluid, it passes with difficulty through orifices by means of which grosser liquids can easily pene-



trate. This has caused philosophers to suppose that its parts were of a branched form\*.

B. The atmospheric air is invisible. It refracts the rays of light without reflecting them: for it is without sufficient proofs that some philosophers have imagined that large masses of this fluid are of a blue colour.

It appears that the air is inodorous itself; though it is the vehicle of odorant particles.

It may be considered as insipid; and when its contact affects us variously, we ought to attribute it to its physical qualities.

C. It was not until the middle of the last century that its weight was ascertained by accurate experiments. The impossibility of supporting water in a tube open at the bottom, to a greater height than thirty-two feet, caused Torricellius to suspect that an external cause supported the liquid at that height, and that it was not the horror of a vacuum which precipitated the water in the barrels of pumps. This celebrated philosopher filled a tube closed at one of its extremities with mercury: he reversed this into a vessel filled with the same metal; and observed that the mercury, after several oscillations, constantly subsided to the height of twenty-eight inches. He immediately saw that the difference of elevations corresponded with the relative weights of these two fluids, which are in the proportion of fourteen to one. The immortal Pascal proved, some time afterwards, that liquids were supported at this elevation by a column of atmospherical air; and he ascertained that their height varies according to the length of the column which presses upon them.

D. The elasticity of the air is one of the properties upon which natural philosophers have made the greatest number of experiments; and it has even been applied to considerable advantage in the arts.

\* This is a deception. It is true that the cohesive attraction renders it difficult to displace any dense fluid from a capillary tube by the intrusion of air; but every experiment of the air-pump, the condenser, and the barometer, shews with what facility the air passes through the smallest orifices. T.

## SECTION VII.

Concerning the Combination of Oxigenous Gas and Hydrogene,  
which forms Water.

**W**ATER has been long considered as an elementary principle; and when accurate experiments had compelled chemists to class it among compound substances, a resistance and opposition were made to it, which were not manifested when the air, the earth, and the other matters reputed to be elementary, were subjected to similar revolutions. It seems to me, however, that this analysis is equally strict with that of air. Water is decomposed by several processes; it is formed by the combination of oxigene and hydrogene: and we find that all the phenomena of nature and art conspire to prove the same truth. What more can be required to afford an absolute certainty respecting any physical fact?

Water is contained in bodies in a greater or less quantity, and may be considered in two states: it is either in the state of simple mixture, or in a state of combination. In the first case, it renders bodies humid, is perceptible to the eye, and may be disengaged with the greatest facility. In the second, it exhibits no character which shews that it is in a state of mixture. It exists in this form in crystals, salts, plants, animals, &c. It is this water which the celebrated Bernard has called Generative Water; and of which he has made a fifth element, to distinguish it from exhalative water.

Water, existing in a state of combination in bodies, concurs in imparting to them hardness and transparency. Salts, and most stony crystals, lose their transparency when they are deprived of their water of crystallization.

Some bodies are indebted to water for their fixity. The acids, for example, acquire fixity only by combining with water.

Under these various points of view, water may be considered as the general cement of nature. The stones and salts which are deprived of it, become pulverulent; and water facilitates the coagulation, re-union, and consistence of the particles of stones, salts, &c. as we shall see in the operations performed with plasters, lutes, mortar, &c.

Water, when disengaged from its combinations, and in a state of absolute liberty, is one of the most considerable agents in the operations of this globe. It bears a part in the formation and decomposition of all the bodies of the mineral kingdom: it is necessary to vegetation, and to the free exercise of most of the functions of animal bodies; and it hastens and facilitates the destruction of these bodies, as soon as they are deprived of the principle of life.

For a certain time water was thought to be a fluid earth. The distillation, trituration, and putrefaction of water, which always left an earthy residue, afforded credit to an opinion that it was converted into earth. On this subject, the works of Wallerius and Margraff may be consulted: but Mr. Lavoisier has shewn that this earth arises from the wear of the vessels; and the celebrated Scheele has proved the identity of the nature of this earth with that of the glass vessels in which the operations were made. So that the opinions of the philosophical world are at present decided in this respect.

In order to obtain accurate ideas of a substance so necessary to be known, we will consider water under its three different states of solidity, fluidity, and gas.

## ARTICLE I.

### Concerning Water in the State of Ice.

Ice is the natural state of water, whenever it is deprived of a portion of that caloric with which it is combined when it appears in the form of a liquid or gas.

The conversion into ice is attended with several phenomena which seldom vary.

A. The first of all, and at the same time the most extraordinary, is a sensible production of heat at the moment in which the water passes to the solid state. The experiments of Messrs. Fahrenheit, Treiwald, Baumé, De Ratte, leave no doubt on this subject; so that the water is colder at the instant of congelation than the ice itself.

A slight agitation of the fluid facilitates its conversion into ice, nearly in the same manner as the slightest motion very frequently determines the crystallization of certain salts. This arises, perhaps, from the circumstance, that by this means the caloric, which is interposed between the particles, and may oppose itself to the production of the phenomenon, may be expressed or disengaged. In proof of this opinion, it is seen that the thermometer rises at the very same instant, according to Fahrenheit.

B. Frozen water occupies a larger space than fluid water: we are indebted to the Academy del Cimento for the proofs of this truth. In their experiments, bomb shells, and the strongest vessels, being filled with water, were burst into pieces by the congelation of this fluid. The trunks of trees are split and divided with a loud noise, as soon as the sap freezes; and so likewise stones are broken in pieces the moment the water with which they are impregnated passes to the state of ice.

C. Ice appears to be nothing more than a confused crystallization. Mr. De Mairan observed that the needle-formed crystals of ice unite in an angle of either sixty or one hundred and twenty degrees.

Mr. Pelletier observed, in a piece of fistulous ice, crystals in the form of flattened triangular prisms, terminated by two dehdral summits.

Mr. Sage observes, that if a piece of ice, which contains water in its internal parts, be broken, the water runs out, and the internal cavity is found to be lined with beautiful tetrahedral prisms, terminated in four-sided prisms. These prisms are often articulated and crossed. Vide M. Sage, *Anales de Chimie*, tom. i. p. 77.

Mr. Macquart has observed, that when it snows at Moscow, and the atmosphere is not too dry, the air is



observed to be loaded with beautiful crystallizations regularly flattened, and as thin as a leaf of paper. They consist of an union of fibres which shoot from the same center to form six principal rays, and these rays divide themselves into small blades extremely brilliant: he observed several of these flattened radii which were ten lines in diameter.

D. When water passes from the solid to the liquid state, it produces cold by the absorption of a portion of heat, as is confirmed by the fine experiments of Wilcke. This production of cold by the fusion of ice, is likewise proved by the practice of the confectioners, who fuse certain salts with ice, in order to produce a degree of cold below 0.

Ice is found in many places in great masses, known by the name of Glacieres: certain mountains are constantly covered with them, and the southern ocean abounds with them. The ice formed by salt water affords fresh water when melted; and in several northern provinces water is said to be concentrated by frost, to collect the salt it holds in solution. I have likewise observed, that several metallic salts are precipitated by exposing their solutions to a temperature sufficient to freeze them. The ice which was formed did not possess the characters of the salt which had been dissolved.

Hail and snow are nothing but modifications of ice. We may consider hail as produced by the sudden disengagement of the elastic fluid, which concurs in rendering water liquid: it is almost always accompanied with thunder. The experiments of Mr. Quinquet have confirmed this theory.—I will here relate a fact to which I myself was witness, at Montpellier, and of which philosophers may advantageously avail themselves. On the 29th of October, 1786, four inches of water fell at Montpellier; a violent explosion of thunder, which was heard about four in the evening, and which appeared to be very near, caused a most dreadful shower of hail. At this instant a druggist, who was employed in his cellar in preventing the mischief occasioned by the filtration of water through the wall, was highly astonished to behold that the water

which came through the wall was instantly changed into ice. He called in several neighbours to partake of his surprise. I visited the place a quarter of an hour afterwards and found ten pounds of ice at the foot of the wall; I was well assured that it could not have passed through the wall, which did not exhibit any crack, but appeared to be in very good condition. Did the same cause, which determined the formation of hail in the atmosphere, act equally in this cellar?—I relate the fact only, and forbear to make any conjecture upon it.

## ARTICLE II.

### Concerning Water in the Liquid State.

The natural state of water appears to be that of ice: but its most usual state is that of fluidity; and under this form it possesses certain general properties, which we shall proceed to describe.

The experiments of the Academy del Cimento have caused the philosophical world to deny the least elasticity to water, because it escaped through the pores of balls of metal strongly compressed, rather than yield to pressure. But Messrs. Zimmerman, and the abbé Mongez, have endeavoured to prove its elasticity from the very experiments upon which the contrary opinion has been built\*.

The liquid state renders the force of aggregation in water less powerful, and it enters into combination more readily in this form. Water which flows on the surface of our globe is never pure. Rain-water is seldom exempt from some mixture, as appears from the fine series of experiments of the celebrated Margraff. I have after-

\* The experiments of Canton, to prove the compressibility of water, are well known, and may be seen in the Philosophical Transactions. He inclosed water in spherical glass vessels, from which a narrow neck proceeded, like that of a thermometer: the water was found to occupy a larger space when the pressure of the atmosphere was removed by the air-pump, and a less space when a greater pressure was added by the condenser. T.

tained;—at Montpellier, that the rain-water in storms is more impure than that of a gentle shower—that the water which falls first is less pure than that which falls after several hours or several days rain—that the water which falls when the wind blows from the sea to the southward, contains sea-salt; whereas that which is produced by a northerly wind, does not contain a particle.

Hippocrates has made several very important observations respecting the various qualities of water, relative to the nature of the soil, the temperature of the climate, &c.

As it is of importance to the chemist to have very pure water for several delicate operations, it is necessary to point out the means which may be used to carry any water whatever to this degree of purity.

Water is purified by distillation. This operation is performed in vessels called Alembics. The Alembic is composed of two pieces; a boiler or cucurbit, and a covering called the capital or head.

The water is put into the cucurbit, from which it is raised in vapours by means of fire, and these vapours are condensed by cooling the head with cold water. The condensed vapours flow into a vessel designed to receive them. This is called Distilled Water; and is pure, because it has left behind it in the cucurbit the salts and other fixed principles which altered its purity.

Distillation is more speedy and quick, in proportion as the pressure of the air is less upon the surface of the stagnant fluid. Mr. Lavoisier distilled mercury *in vacuo*; and the abbé Rochon has made a happy application of these principles to distillation. It is to this same principle that we must refer the observations of almost all naturalists and philosophers, who have remarked, that the ebullition in the liquid becomes more easy, in proportion as we ascend a mountain from any other elevation; and it is in consequence of these principles, that Mr. Achard constructed an instrument to determine the heights of mountains, by the degrees of temperature of the ebullition of boiling water.

The abbé Mongez, and Mr. Lamanow, observed that ether evaporates with prodigious facility upon the peak

of Teneriffe; and Mr. De Saussure has confirmed these experiments on the mountains of Switzerland.

A true distillation is carried on every where at the surface of our globe. The heat of the sun raises water in the form of vapours; these remain a certain time in the atmosphere, and afterwards fall in the form of dew, by simple refrigeration. This rise and fall of humidity, which succeed each other, wash and purge the atmosphere of all those particles, which by their corruption or development might render it infectious; and it is perhaps this combination of various miasmata with water which renders the evening dew so unwholesome.

It is to a similar natural distillation that we ought to refer the alternate transition of water from the liquid state to that of vapour, which forms clouds, and by this means conveys the water from the sea to the summits of mountains, from which it is precipitated in torrents, to return again to the common receptacle.

We find traces of the distillation of water in the most remote ages. The first navigators in the islands of the Archipelago filled their pots with salt-water, and received the vapour in sponges placed over them. The process of distilling the water of the sea has been successively brought to perfection; and Mr. Poissonnier has exhibited a very well constructed apparatus to procure fresh water at all times in abundance.

Pure water requires to be agitated, and combined with the air of the atmosphere, to render it wholesome. Hence, no doubt, it is, that water immediately produced by melting snow, is unfit to drink.

The characters of potable water are the following:

1. A lively, fresh, and agreeable taste.
2. The property of boiling readily, and also that of boiling pease, and other pulse.
3. The virtue of dissolving soap without curdling.



## ARTICLE III.

## Concerning Water in the State of Gas.

Many substances are naturally in the state of an aëri-form fluid, at the degree of the temperature of our atmosphere: such, for example, are the carbonic acid; and the oxygenous, the hydrogenous, and the nitrogenous gases.

Other substances evaporate at a degree of heat very near that in which we live. Ether and alcohol are in this situation. The first of these liquors passes to the state of gas at the temperature of 35 degrees; the second, at that of 80 (of Reaumur).

Some fluids require a stronger heat for this purpose; such as water, the sulphuric and nitric acids, oil, &c.

To convert water into an aëri-form fluid, Messrs. De la Place and Lavoisier filled a glass vessel with mercury, and reversed it over a dish filled with the same metal. Two ounces of water were transferred beneath this vessel; and the mercury was heated to the temperature of between ninety-five and a hundred of Reaumur, by plunging it in a boiler filled with the mother water of nitre. The included water became rarefied, and occupied the whole capacity.

Water, by passing through earthen vessels ignited in the fire, becomes converted into gas, according to Priestley and Kirwan. The æolipile, the steam-engine, the digester of Papin, and the process of the glass-blowers, who blow large globes by injecting a mouthful of water through their iron tube, prove the conversion of water into gas.

It follows from these principles, that the volatilization of water being nothing more than a direct combination of caloric with this liquid, the portions of water which are the most immediately exposed to heat, must be the first volatilized: and this is daily observed; for it is continually seen that ebullition begins at the part most heated. But

when the heat is applied equally at all parts, the ebullition is general.

Several phenomena have led us to believe that water may be converted into air. The process of the glass-blowers to blow large spheres; the hydraulic organ of father Kircher; the phenomena of the æolipile; the experiments of Messrs. Priestley and Kirwan; the manner of assisting combustion, by sprinkling a small quantity of water upon the coals—all these circumstances appeared to announce the conversion of water into air. But it was far from being supposed that most of these phenomena were produced by the decomposition of this fluid; and the genius of Mr. Lavoisier was necessary to carry this point of doctrine to the degree of certainty and precision, which in my opinion it now appears to possess.

Messrs. Macquer and De la Metherie had already observed, that the combustion of inflammable air produced much water. Mr. Cavendish confirmed these experiments in England, by the rapid combustion of inflammable air and vital air. But Messrs. Lavoisier, De la Place, Monge, and Meusnier, have proved that the whole mass of the water might be converted into hydrogen and oxygen; and that the combustion of these two gases produced a volume of water proportioned to the weight of the two principles employed in this experiment.

1. If a small glass vessel be inverted over mercury, and a known quantity of distilled water and filings of iron be put into the upper part of this vessel, inflammable air will be gradually disengaged, the iron will rust, and the water which moistens it will diminish, and at length disappear; the weight of the inflammable air which is produced, and the augmentation in weight of the iron, will be equivalent to the weight of the water made use of. It appears therefore to be proved, that the water is reduced into two principles, the one of which is inflammable air, and the other is the principle which has entered into combination with the metal. Now we know that the oxidation or calcination of metals is owing to vital air; and consequently the two substances produced, namely the

vital air and inflammable air, arise from the decomposition of water.

2. When water is converted into the state of vapour, in its passage through an ignited iron tube, the iron becomes oxidized, and hydrogen is obtained in the state of gas. The augmentation of weight in the metal, and the weight of the hydrogen obtained form precisely a sum equal to that of the water employed.

The experiment made at Paris, in the presence of a numerous commission of the Academy, appears to me to leave no further doubt concerning the decomposition of water.

A gun-barrel was taken, into which a quantity of thick iron wire, flattened by hammering, was introduced. The iron and the gun-barrel were weighed: the gun-barrel was then covered with a lute proper to defend it from the contact of the air; it was afterwards placed in a furnace, and inclined in such a manner as that water might run through it. At its most elevated extremity was fixed a funnel designed to contain water, and to let it pass drop by drop by means of a cock: this funnel was closed, to avoid all evaporation of the water. At the other extremity of the gun-barrel was placed a tubulated receiver, intended to receive the water which might pass without decomposition; and to the tubulure of the receiver the pneumato-chemical apparatus was adapted. For greater precaution, a vacuum was made in the whole apparatus before the operation began. Lastly, as soon as the gun-barrel was red-hot, the water was introduced drop by drop. Much hydrogenous gas was obtained: and at the end of the experiment the gun-barrel was found to have acquired weight; and the flat pieces of iron included within were converted into a stratum of black oxide of iron; or Ethiops martial, crystallized like the iron ore of the island of Elba. It was ascertained that the iron was in the same state as that which is burned in oxygenous gas; and the increased weight of the iron, added to that of the hydrogen, was accurately equal to that of the water employed.

The hydrogenous gas obtained was burned with a quantity of vital air equal to that which had been retained by the iron, and the six ounces of water were recomposed.

3. Messrs. Lavoisier and De la Place, by burning in a proper apparatus a mixture of fourteen parts of hydrogenous gas, and eighty-six of oxigene, obtained a proportionate quantity of water. Mr. Monge obtained the same result at Mezieres, at the same time.

The most conclusive and the most authentic experiment which was made upon the composition or synthesis of water, is that which was begun on the 23d of May, and ended on the 7th of June, 1788, at the Royal College, by Mr. Lefevre de Gineau.

The volume of oxigenous gas consumed, when reduced to the pressure of twenty-eight inches of mercury, at the temperature of ten degrees of the thermometer of Reaumur, was 35085 (French) cubic inches, and its weight 250 gros 10,5 grains.

The volume of hydrogenous gas was 74967,4 cubic inches, and the weight 66 gros 4,3 grains.

The nitrogenous gas and the carbonic acid which were mixed with these gases, and which had been extracted out of the receiver at nine several times, weighed 39,23 grains.

The oxigenous gas contained  $\frac{1}{8}$  of its weight of carbonic acid; so that the weight of these gases burned was 280 gros 63,8 grains which makes 2 pounds 3 ounces 0 gros 63,8 grains.

The vessels were opened in the presence of the gentlemen of the Academy of Sciences, and several other learned men, and were found to contain 2 pound 3 ounces 0 gros 33 grains of water: this weight answers to that of the gases made use of, wanting 31 grains; this deficiency may arise from the caloric which held the gases in solution being dissipated when they became fixed, which must necessarily have occasioned a loss.

The water was subacid to the taste, and afforded 27½ grains of nitric acid, which acid is produced by the combination of the nitrogene and oxigene gases.



From the experiment of the decomposition of water, 100 parts of this fluid contained

Oxigene  $84,2636 = 84\frac{1}{4}$ .

Hydrogene  $15,7364 = 15\frac{1}{4}$ .

According to the experiment of its composition, 100 parts of water contained

Oxigene  $84,8 = 84\frac{4}{5}$ .

Hydrogene  $15,2 = 15\frac{1}{5}$ .

Independent of these experiments of analysis and synthesis, the phenomena exhibited by water, in its several states, confirm our ideas with regard to the constituent parts which we acknowledge it to possess. The oxidation of metals in the interior parts of the earth, at a distance from the atmospherical air, the efflorescence of pyrites, and the formation of ochres, are phenomena which cannot be explained without the assistance of this theory.

Water being composed of two known principles, must act like all other compound bodies which we know; that is, according to the affinities of its constituent parts. It must therefore in some instances yield its hydrogene, and in others its oxigene.

If it be placed in contact with bodies which have the strongest affinity with oxigene, such as the metals, oils, charcoal, &c. the oxigenous principle will unite with these substances; and the hydrogene, being set at liberty, will be dissipated. This happens when hydrogene gas is disengaged, by causing the acids to act upon certain metals; or when red-hot iron is plunged in water, as Messrs. Hassenfratz, Stoulfz, and D'Hellancourt have observed.

In vegetables, on the contrary, it seems that the hydrogene is the principle which fixes itself; while the oxigene is easily disengaged, and makes its escape.

## SECTION VIII.

Concerning the Combinations of Nitrogene Gas. 1. With Hydrogene Gas. 2. With the Earthy principles forming the Alkalis.

IT appears to be proved, that the combination of nitrogene gas with hydrogene forms one of the substances comprised in the class of alkalis. It is very probable that the others are composed of this same gas and an earthy basis. It is from these considerations that we have thought proper to place those substances here: and we have adopted that decision with so much the more foundation, because the knowledge of alkalis is indispensably necessary to enable us to proceed with order in a course of chemistry; and because these re-agents are most frequently employed, and their combinations and uses present themselves at every step in the phenomena of nature and art.

It is an established convention to call every substance an Alkali, which is characterised by the following properties:

A. An acrid, burning, urinous taste.

B. The property of converting syrup of violets green; but not the tincture of turnsole, as certain authors announce.

C. The virtue of forming glass, when fused with quartzose substances.

D. The faculty of rendering oils miscible with water; of effervescing with certain acids; and of forming neutral salts with all of them.

I must observe that none of these characters is rigorous and exclusive; and that consequently no one of them is sufficient to afford a certainty of the existence of an alkali: but the re-union of several form, by their concurrence, a mass of proofs or indications, which lead us to sufficient evidence.

The alkalis are divided into fixed alkalis, and volatile alkalis. This distinction is established upon the smell of these substances: the former are not volatilized, even in the focus of the burning mirror, and emit no characteristic smell; whereas the latter are easily reduced into vapour, and emit a very penetrating odour.

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## CHAPTER I.

*Concerning Fixed Alkalis.*

NO more than two kinds of fixed alkalis have hitherto been discovered: the one which is called Vegetable Alkali, or Pot-Ash; the other Mineral Alkali, or Soda.

## ARTICLE I.

## Concerning the Vegetable Alkali, or Pot-Ash.

This alkali may be extracted from various substances; and it is more or less pure, accordingly as it is afforded by one substance or another. Several varieties are made in commerce, to which different names have been affixed, and which are indispensably necessary to be known. The chemist may indeed confound all these distinctions, in his writings, under one single denomination: but the distinctions established by the artists are founded upon a series of experiments, which have proved that the virtues of these several alkalis are very different; and this constant variety in their effects appears to me to justify the various denominations assigned them.

1. The alkali extracted from the lixivium of wood-ashes, is known by the name of *Salin*. The *salin* calcined, and by this means disengaged from all the blackening principles, forms pot-ash.

The ashes are more or less rich in alkali, according to the nature of the wood which affords them; in general, hard woods contain the most. The ashes of beech afford from 11 to 13lb. per quintal, according to the experiments which I have made in the large way, at St. Saviour; those of box afforded from 12 to 14lb. The tables drawn up by the several administrators of the gunpowder and saltpetre manufactories may be consulted, respecting the quantity of alkali afforded by the combustion of several plants: they used 4000lb. of each in their various experiments.

To extract this alkali, nothing more is necessary than to wash the ashes, and to concentrate the dissolution in boilers of cast iron. It is on account of the alkali that wood-ashes are employed in the lixiviums used by laundresses or bleachers. The use of alkali, in this case, is to combine with the fat substances, and to render them soluble in water.

Almost all the pot-ash sold in commerce for the use of our glass-houses, our soap-makers, our bleaching-grounds, &c. is fabricated in the north, where the abundance of wood admits of its being applied to this single purpose. We might establish works of this kind to sufficient advantage in the forests of our kingdom. But there is more to be done than is generally supposed, before the inhabitants of the mountains can be turned towards this species of industry. I have experienced this difficulty in the attempts and very considerable sacrifices which I have made, to secure this resource in the neighbourhood of Laigoual and Lesperou. The accurate calculations which I have made, have nevertheless proved that the pot-ash would cost only from 15 to 17 livres the quintal, whereas we purchase that from the north at 30 or 40 livres.

2. The lees of wine is almost totally converted into alkali by combustion. This alkali is called *Cendres Gravelées*: it has almost always a greenish colour. This alkali is considered as very pure.

3. The combustion of tartar of wine likewise affords an alkali of considerable purity. It is usually burned wrapped up in paper, in small packets, which are dipped in



water, and afterwards exposed upon burning coals. In order to purify it, the residue of the combustion is dissolved in water, the solution concentrated by fire, the foreign salts separated in proportion as they precipitate; and a very pure alkali is at last obtained, which is known by the name of Salt of Tartar.

To procure salt of tartar more speedily, as well as more economically, I burn a mixture of equal parts of nitrate of pot-ash, or common nitre and tartar. The residue, after lixiviation, affords a beautiful salt of tartar.

Salt of tartar is the alkali most commonly employed in medical uses; it is given in the dose of several grains.

4. If saltpetre be fused upon charcoal, the acid is decomposed and dissipated, while the alkali remains alone and disengaged: this is called *Extemporaneous Alkali*.

When the vegetable alkali has been brought to the greatest state of purity, it attracts the humidity of the air, and is resolved into a liquor. In this state it is known by the very improper name of *Oil of Tartar per Deliquium*.

## ARTICLE II.

### Concerning the Mineral Alkali, or Soda.

The Mineral Alkali has been so called, because it forms the basis of marine salt.

It is obtained from marine plants by combustion: for this purpose heaps of the saline plants are formed; and at the side of these heaps a round cavity is dug, which is enlarged towards the bottom, and is three or four feet in depth: this is the fire-place in which the vegetables are burned. The combustion is kept up without interruption for several days; and when all the plants are consumed, a mass of alkaline salt is found remaining, which is cut into pieces, to facilitate its carriage and sale. This is known by the name of *Rock Soda* or *Soda*.

All marine plants do not afford soda of the same quality. The barilla of Spain affords the beautiful soda of Alicant. I am assured that we might cultivate it upon our coasts in the Mediterranean, with the greatest

success. This culture is highly interesting to the arts and commerce; and government ought to encourage this new species of industry. But an individual, however inclined or devoted to the public good, might make vain efforts to appropriate this commerce to our advantage, if he were not powerfully assisted by government; because the Spanish ministry has prohibited the exportation of the seed of barilla, under the strongest penalties. In Languedoc, and in Provence, we cultivate on the banks of our ponds a plant known by the name of Salicor, which affords soda of a good quality; but the plants which grow without cultivation produce an inferior sort. I have made an accurate analysis of each species, the results of which may be seen at the article *Verrerie* of the *Encyclopedie Methodique*.

The mineral alkali is cleared of all heterogeneous salts by dissolving it in water, and separating the several salts in proportion as they fall down. The last portion of the fluid being concentrated affords the soda, which crystallizes in rhomboidal octahedrons.

The mineral alkali is sometimes found in a native state: in Egypt it is known by the name of Natron. The two lakes of Natron described by Sicard and Mr. Volney, are situated in the desert of Chaiat, or St. Macaire, to the west of Delta. Their bed is a natural cavity of three or four leagues in length, and a quarter of a league in breadth; the bottom is solid and stony. It is dry during nine months in the year; but in winter a water of a violet-red colour oozes out of the earth, which fills the lake to five or six feet in depth: the return of the heat of summer evaporates this, and leaves a bed of salt behind it of two feet in thickness, which is dug out with bars of iron. The quantity obtained annually amounts to 36,000 quintals.

Mr. Proust found natron upon the schisti which form the foundation of the town of Angers; the same chemist likewise found it upon a stone from the salpetriere of Paris.

The mineral alkali differs from the vegetable, because  
—1. It is less caustic. 2. It is so far from attracting

humidity, that it effloresces in the air. 3. It crystallizes in rhomboidal octahedrons. 4. It forms different products with the same bases. 5. It is more proper for vitrification.

Do the alkalis exist ready formed in vegetables, or are they the product of the several operations made use of in extracting them?—This question has divided the opinions of chemists. Du Hamel and Grosse proved, in 1732, the existence of alkali in cream of tartar, by treating it with the nitric, sulphuric, and other acids. Margraff has given additional proofs of this, in a Memoir which forms the twenty-fifth of his collection. Rouelle read a Memoir to the academy on the 14th of June, 1769, upon the same subject: he even affirms that he was acquainted with this truth before the work of Margraff appeared.—See the *Journal De Physique*, vol. i.

Rouelle, and the marquis De Bullion, proved that tartar exists in must.

It must not be concluded from the existence of an alkali in vegetables, that this salt is there found in a disengaged state. On the contrary, it is found combined with acids, oils, &c.

The alkalis, such as we have described them, even after they have been disengaged from every mixture, by solution, filtration, and evaporation, are not nevertheless in that state of purity and disengagement, which is necessary to be obtained in many cases: they are nearly in the state of neutral salts, by their combination with the carbonic acid. When it is required to disengage this acid, the alkali must be dissolved in water, and quick lime then slacked in the solution. This substance seizes the carbonic acid of the alkali, and gives out its caloric in exchange. We shall speak of the circumstances of this operation when we shall have occasion to treat of lime. The alkali being deprived of the carbonic acid, no longer effervesces with other acids; it is more caustic, and more violent in its action; unites more easily to oils; and is then called *Caustic Alkali*, *Pure Pot-ash*, or *Pure Soda*.

When this alkali is evaporated, and brought into the dry form, it is known by the name of *Lapis Causticus*.

The corrosive virtue of this substance depends principally upon the avidity with which it seizes humidity, and falls into deliquium.

The caustic alkali, as it is usually prepared, always contains a small quantity of carbonic acid, siliceous earth, iron, lime, &c. Mr. Berthollet has proposed the following means of purifying it:—He concentrates the caustic lixivium until it has acquired a slight degree of consistence; at which period he mixes it with alcohol, and draws off a portion by distillation. As soon as the retort is become cold, he finds it to contain crystals, mixed with a blackish earth, in a small quantity of liquor of a dark colour, which is separated from the solution of alkali, in the alcohol, which swims above like an oil. These crystals consist of the alkali saturated with the carbonic acid, and are insoluble in spirit of wine; the deposition consists of siliceous earth, lime, iron, &c.

The caustic alkali in a state of great purity, dissolved in the alcohol, swims above the aqueous solution which contains the effervescent alkali. If the spiritous solution of alkali be concentrated on the sand-bath, transparent crystals are formed, which consist of the pure alkali itself: these crystals appear to be formed by quadrangular pyramids inserted one in another; they are very deliquescent, are soluble in water and in alcohol, and produce cold by their solution.—See the *Journal de Physique*, 1786, page 401.

The alkalis we have just spoken of, combine easily with sulphur.

This combination may be effected—1. By the fusion of equal parts of alkali and sulphur. 2. By digesting the pure and liquid alkali upon sulphur.—In these cases the alkali becomes of a reddish yellow-colour.

The solutions of sulphur in alkali are known by the name of *Livers of Sulphur*, *Sulphures of Alkali*, &c. They emit an offensive smell, resembling that of rotten eggs. This is occasioned by the escape of the stinking gas, called *Hepatic Gas*.

The sulphur may be precipitated by acids; and the result of this precipitation is what the ancient chemists



distinguished by the name of Milk of Sulphur, and Magistery of Sulphur.

These sulphures or hepars dissolve metals. Gold itself may be so divided by this means as to pass through filters. Stahl has supposed that Moses made use of this method to enable the Israelites to drink the golden calf.

Though the analysis of the two alkalis has not been made with strictness, several experiments lead us to believe that nitrogen is one of their principles. Mr. Thouvenel, having exposed washed chalk to the exhalations of animal substances in putrefaction, obtained nitrate of pot-ash, or common nitre. I have repeated this experiment in a closed chamber of six feet square. Twenty-five pounds of chalk well washed in warm water, and exposed to the exhalation of bullock's blood in putrefaction during eleven months, afforded nine ounces of nitrate of lime, in a dried state; and three ounces one gros of crystals of nitrate of pot-ash, or common nitre.

The repeated distillation of soaps decomposes them, and affords ammoniac. Now the analysis of this last, by Mr. Berthollet, proves the existence of nitrogenous gas as one of its constituent parts. There is therefore room to apprehend that nitrogen gas is one of the principles of alkalis.

The experiments of Mr. Thouvenel, as well as my own, lead to believe that this gas when combined with lime, forms pot-ash, or the vegetable alkali; while its union with magnesia forms soda. This last opinion is supported by the experiments—1. Of Dehne, who obtained magnesia from soda (see Croll's Chemical Annals, 1781, page 53). 2. Of Mr. Deyeux, who obtained similar results, even before Mr. Dehne. 3. Of Mr. Lorgna, who obtained much magnesia by dissolving, evaporating, and calcining soda repeatedly (Journal de Physique, 1787). Mr. Osburgh confirmed these various experiments in 1785.

## CHAPTER II.

*Concerning Ammoniac, or the Volatile Alkali.*

OUR researches have not hitherto exhibited more than one species of volatile alkali. Its formation appears to be owing to putrefaction; and though the distillation of some schisti affords it, yet this circumstance may be attributed to their origin, which is pretty generally ascribed to vegetable and animal decomposition. We find frequently enough, in these substances, the print of fishes, which is in favour of this opinion. Some plants likewise afford volatile alkali; for which reason they have been called Animal Plants. But the volatile alkali is more especially afforded by animal substances: the distillation of all their parts affords it in considerable abundance. Horns are employed in preference, because they are resolved almost entirely into oil and volatile alkali. The putrefaction of all animal substances produces volatile alkali; and in this case, as well as in distillation, it is formed by the combination of its two constituent parts: for the analysis very often fails in exhibiting any alkali ready formed, in such parts as distillation or putrefaction would abundantly afford it from.

Almost all the volatile alkali made use of in commerce or medicine, is afforded by the decomposition of sal ammoniac. It is even on account of this circumstance, that the chemists who have drawn up the New Nomenclature, have distinguished the volatile alkali by the name of Ammoniac.

To obtain ammoniac in a state of considerable purity, equal parts of sifted quick-lime and muriate of ammoniac, or common sal ammoniac in powder, are mixed. This mixture is then introduced into a retort, to which a receiver and the apparatus of Woulfe have been adapted. A quantity of pure water is to be put into the bottles,

correspondent to the weight of the salt employed; and the junctures of the vessels are made good with the usual lutes. The ammoniac is disengaged in the state of gas, at the first impression of the fire. It combines with the water with heat; and when the water of the first bottle is saturated, the gas passes to that of the second, and saturates it in its turn.

Volatile alkali is known by its very strong but not disagreeable smell. It is easily reducible into the state of gas, and preserves this form at the temperature of the atmosphere. This gas may be obtained by decomposing the muriate of ammoniac by quick-lime, and receiving the the product over mercury.

Alkaline gas kills animals, and corrodes the skin. The irritation is such, that I have seen pimples arise all over the bodies of some birds exposed to its atmosphere.

This gas is improper for combustion; but if a taper be gently immersed in it, the flame is enlarged before it goes out, and the gas suffers a decomposition. Alkaline gas is lighter than atmospheric air; and has even been mentioned, on account of its lightness, as a proper substance to fill balloons. The count De Milly proposed to place a brazier, or vessel containing fire, under the balloon, to keep the gas in its greatest state of expansibility.

The experiments of Dr. Priestley, who changed alkaline gas into hydrogen gas by means of the electric spark; those of the chevalier Laudriani, who, by passing the same gas through ignited glass tubes, obtained a large quantity of hydrogenous gas—occasioned a suspicion of the existence of hydrogen among the principles of alkaline gas. But the experiments of Mr. Berthollet have removed all doubts on this subject; and all observations appear to unite in authorising us to consider this alkali as a compound of the nitrogenous and hydrogenous gases.

1. If the oxygenated muriatic acid be mixed with very pure ammoniac, an effervescence takes place, with a disengagement of nitrogenous gas, a production of water, and a conversion of the oxygenated acid into the ordinary muriatic acid. In this beautiful experiment, the water which is produced is formed by the combination of the

hydrogene of the alkali and the oxigene of the acid; and the nitrogene gas being set at liberty, is dissipated.

2. When the nitrate of ammoniac is exposed to distillation, nitrogene gas is obtained, and a greater quantity of water is found in the receiver than the salt itself contained. After the operation, the ammoniac is found no longer to exist. The water of the receiver is slightly charged with a small quantity of nitric acid, which had passed over. In this case, the hydrogene of the alkali, and the oxigene of the acid, from the water in the receiver, while the nitrogenous gas escapes.

If the oxides of copper or gold be heated with ammoniacal gas, the product is water and nitrogenous gas, and the metals are reduced.

I have observed that the oxides of arsenic, being digested with ammoniac, are reduced, and often form octahedral crystals of arsenic. In this case there is a disengagement of nitrogene gas, and a formation of water.

It very often happens when metals, such as copper or tin, are dissolved by means of the nitric acid, that an absorption of air takes place, instead of a disengagement of nitrous gas, as might be expected: I have seen several persons very much embarrassed in such cases, and I have often been so myself. This phenomenon takes place more especially when a very concentrated acid is made use of, and the copper is in fine filings: in this case ammoniac is produced. I have shown this fact to my auditors long before I was acquainted with the theory of its formation. That which led me to suspect its existence, was the blue colour which the solution takes in this case. This ammoniac is produced by the combination of the hydrogene of the water with the nitrogene gas of the nitric acid; while the oxigene of the same acid, and that of the water, oxidized the metal, and prepared it for solution. It is to a similar cause that we must refer the experiment of Mr. John Michael Hauffman of Colmar, who by passing nitrous gas through a certain quantity of precipitate of iron, in the mercurial apparatus, observed that this gas was speedily absorbed, and the colour of the iron changed;



at the same time that vapour of ammoniac was found in the vessels. It is by a similar theory we may account for the formation of alkaline gas, by the mixture of hepatic gas and nitrous gas over mercury, as Mr. Kirwan observes.

Mr. Austin formed ammoniac; but he observed that the combination of nitrogenous gas with the base of hydrogene does not take place unless this last is in a state of great condensation.

The formation of ammoniac by distillation and putrefaction, appears to me likewise to indicate its constituent parts. In fact, there is in both these operations a disengagement of hydrogene and nitrogen gas, and their combination produces ammoniac.

Mr. Berthollet has proved, by the way of decomposition, that one thousand parts of ammoniac, by weight, are composed of about eight hundred and seven of nitrogen gas, and one hundred and ninety-three of hydrogen gas.—See the collection of the Royal Academy, 1784, page 316.

According to Dr. Austin, the nitrogen gas is in proportion to the hydrogene, as one hundred and twenty-one to thirty-two.

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## SECTION IX.

Concerning the Combination of Oxigene with certain Bases forming  
Acids.

IT appears to be out of doubt, that the bodies which we are agreed to call Acids, are combinations of vital Air with a certain elementary substance. The analysis of almost all the Acids, whose component parts are known, establishes this truth in a positive manner; and it is on account of this property that the denomination of Oxigenous Gas has been given to vital air.

Every substance which possesses the following properties is called an Acid :

A. The word *sour*, which is usually employed to denote the impression or lively and sharp sensation produced on the tongue by certain bodies, may be regarded as synonymous to the word *acid*. The only difference which may be established between them is, that the one denotes a weak sensation, whereas the other comprehends all the degrees of force from the least perceptible taste to the greatest degree of causticity. We say, for example, that verjuice, gooseberries, or lemons, are *sour*; but we use the word *acid* to express the impression which the nitric, sulphuric, or muriatic acids make upon the tongue.

The causticity of acids appears to arise from their strong tendency to combination; and it is from this property that the immortal Newton has defined them to be bodies which attract and are attracted.

It is likewise from this property that certain chemists have supposed acids to be pointed bodies.

On account likewise of this decided tendency to combination which acids possess, it seldom happens that we find them in a disengaged state.

B. A second property of acids is that of changing certain blue vegetable colours into red, such as the colour of turnsole, syrup of violets, &c. These two re-agents are commonly used to ascertain the presence of acids.

The tincture of turnsole is prepared by lightly infusing in water that substance which is known in common under the name of Turnsole or Litmus. If the water be too highly charged with the colouring matter, the infusion has a violet tinge, and must in that case be diluted with water until it becomes blue. The tincture of turnsole, when exposed to the sun, becomes red, even in closed vessels; and some time afterwards the colouring part is disengaged, and falls down in the form of a mucilaginous discoloured substance. Alcohol may be used instead of water in the preparation of this tincture.

It is generally supposed that the turnsole fabricated in Holland is nothing more than the colouring matter extracted from the rags or cloths of turnsole of Grand-

Galargues, and precipitated upon a marly earth. These rags are prepared by impregnating them with the juice of nightshade (morelle), and exposing them to the vapour of urine, which develops their blue colour. The rags are sent into Holland, which has given rise to the opinion that they are used in the fabrication of turnsole; but subsequent enquiries have taught me that these cloths are sent to the dealers in cheese, who extract a colour by infusion, and wash their cheeses with it, to give them a red colour. I am convinced, by the analysis of turnsole, that the colouring matter is of the same nature as that of archil (orseille): and that this principle is fixed on a calcareous earth, and a small quantity of pot-ash. In consequence of this analysis, I have endeavoured to cause the liken parellus of Auvergne to ferment with urine, lime, and alkali; and I obtained a paste similar to that of turnsole. The addition of alkali appears to me to be necessary to prevent the development of the red colour, which when combined with the blue, forms the violet of the archil.

When any concentrated acid is to be tried with syrup of violets, there are two particulars to be attended to: 1. The syrup of violets is often green, because the petal of the violet contains a yellow part at its base, which, when combined with the blue, forms this green colour: it is therefore essential to employ only the blue of the petal in order to have a beautiful blue infusion. 2. Care must be taken to dilute the syrup with a certain quantity of water; because otherwise concentrated acids, such as the sulphuric, would burn it, and form a coal.

The simple infusion of violets may be used instead of the syrup.

The colouring matter of indigo is not sensible to the impression of acids. The sulphuric acid dissolves it, without altering the colour.

C. A third character of acids is, that they effervesce with alkalis; but this property is not general. 1. Because the carbonic acid, and almost all weak acids, cannot be distinguished by this property. 2. Because the purest alkalis combine with acids, without motion or effervescence.

Is there not one single acid in nature, of which the others may be only modifications?

Paracelsus admitted an universal principle of acidity, which communicated taste and solubility to all its compounds.

Becher believed that this principle was composed of water and vitrifiable earth. Stahl endeavoured to prove that the sulphuric acid was the universal acid; and his opinion was adopted by most chemists for a long time.

Long after the time of Stahl, Meyer maintained that the acid element was contained in fire. This system, which is founded on certain known facts, has had its supporters.

The chevalier Landriani imagined he had succeeded in reducing all the acids to the carbonic acid; because, by treating them all with different substances, he obtained this last as the constant result of his analysis. He was led into an error, for want of having sufficiently attended to the decomposition of the acids he made use of, and the combination of their oxigene with the carbone of the bodies which entered into his experiments, and produced the carbonic acid.

Lastly, the strict analysis and synthesis of most of the known acids, have proved to Mr. Lavoisier that oxigene is the base of all of them; and that their differences and varieties arise only from the substance with which this common principle is combined.

Oxigene united with metals forms oxides; and among these last there are some which possess acid characters, and are classed amongst acid substances.

Oxigene combined with inflammable substances, such as sulphur, carbone, and oils, forms other acids.

The action of acids upon bodies in general cannot be understood but by founding our explanations upon the data which we have established respecting the nature of their constituent parts.

The adhesion of oxigene to the base is more or less strong in the several acids, and consequently their decomposition is more or less easy; as, for example, in metallic solutions, which do not take place excepting when the



metal is in the state of an oxide. The acid which will yield its oxigene with the greatest facility to oxide the metal, will have the most powerful action upon it. Hence it happens, that the nitric and the nitro-muriatic acids are those which dissolve metals the most readily; and hence likewise it happens that the muriatic acid dissolves the oxides more easily than the metals, while the nitric acid acts contrariwise: hence also it arises that this last acts so powerfully upon oils, &c.

It is impossible to conceive and explain the various phenomena presented to us by acids in their operations, if we have no idea of their constituent principles. Stahl would not have believed in the formation of sulphur, if he had understood the decomposition of the sulphuric acid upon charcoal; and if we except the combinations of acids with alkalis, and with certain earths, these substances are either totally or partially decomposed in all the operations made with them upon metals, vegetables, and animals, as we shall find by observing the several phenomena exhibited in these cases respectively.

We shall at present treat only of some of the acids, and shall direct our attention to the others in proportion as we shall have occasion to treat of the various substances which afford them: we shall attend in preference to those which are the best known, and which have the greatest influence in the operations of nature, as well as in those of our laboratories.

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## CHAPTER I.

### *Concerning the Carbonic Acid.*

THIS acid is almost always observed in the state of gas. We find that the ancients were in some measure acquainted with it. Van Helmont called it Gas Silvestre,

the gas of must, or of the vintage. Becher himself had a considerably accurate notion of it, as appears by the following passage: “*Distinguitur autem inter fermentationem apertam et clausam; in apertâ potus fermentatus sanior est, sed fortior in clausâ: causa est, quod evaporatione rarefacta corpuscula, imprimis magna adhuc silvestrium spirituum copia, de quibus antea egimus, retineatur, et in ipsum potum se precipitet, unde valde eum fortem reddit.*”

Hoffmann attributed the virtue of most mineral waters to an elastic spirit contained in them.

Mr. Venel, a celebrated professor in the schools at Montpellier, proved in 1750, that the waters of Seltzer owed their virtue to a superabundant portion of air.

In 1755, Dr. Black of Edinburgh advanced that limestone contains much air of a different nature from common air. He affirmed that the disengagement of this air converted it into lime, and that by the restoration of this air calcareous stone was regenerated. In the year 1746, Dr. M'Bride supported this doctrine with new facts. Mr. Jacquin, professor of Vienna, resumed the same pursuit, multiplied experiments on the manner of extracting this air, and added other proofs in confirmation that the absence of the air rendered alkalis caustic, and formed lime. Dr. Priestley exhibited all the perspicuity and precision on this subject which might be expected from his abilities, and his skill in making experiments of this kind. This substance was then known by the name of Fixed Air. In 1772, Bergmann proved that it is an acid, which he called by the name of Aerial Acid. Since the time of this celebrated chemist, it has been distinguished by the names of Mephitic acid, Cretaceous acid, &c.: and as soon as it was proved to consist of a combination of oxigene and carbone, or pure charcoal, the name of Carbonic acid was appropriated to it.

The carbonic acid is found in three different states.  
1. In that of gas. 2. In a state of mixture. 3. In a state of combination.

It is found in the state of gas at the Grotto del Cano, near Naples; at the well of Perols, near Montpellier;

in that of *Negrae* in Vivarais; upon the surface of the Lake *Averno* in Italy, and on those of several springs; in various subterraneous places, such as tombs, cellars, necessaries, &c. It is disengaged in this form by the decomposition of vegetables heaped together, by the fermentation of wine or beer, by the putrefaction of animal matters, &c.

It exists in the state of simple mixture in mineral waters, since in these it possesses all its acid properties.

It exists in a state of combination in stone, common *magnesia*, alkalis, &c.

Various processes are employed to collect it, according to the state in which it is found.

I. When the carbonic acid exists in the state of gas, it may be collected—1. By filling a bottle with water, and emptying it into the atmosphere of this gas: the acid takes the place of the water, and the bottle is afterwards corked to retain it. 2. By exposing lime-water, caustic alkalis, or even pure water, in its atmosphere: the gaseous acid mixes or combines with these substances; and may be afterwards extracted by re-agents, which we shall proceed to describe.

II. When the carbonic acid exists in a state of combination, it may be extracted—1. By distillation with a strong heat. 2. By the re-action of other acids, such as the sulphuric acid, which has the advantage of not being volatile, and consequently is not altered by its mixture with the carbonic acid which is disengaged.

III. When the carbonic acid exists in the state of simple mixture, as in water, brisk wines, &c. it may be obtained—1. By agitation of the liquid which contains it; as Mr. *Venel* practised, by making use of a bottle to which he adapted a moistened bladder.

2. By distillation of the same fluid.—These two first methods are not accurate.

3. The process indicated by Mr. *Gioanetti*, consists in precipitating the carbonic acid by means of lime-water, weighing the precipitate, and deducting thirteen thirty-second parts for the proportion of carbonic acid; it having been deduced from analysis, by this celebrated physician,

that thirty-two parts of carbonate of lime contain seventeen lime, two water, and thirteen acid.

This substance is an acid, as is proved—1. Because tincture of turnsole, agitated in a bottle filled with this gas, becomes red. 2. Ammonic, or volatile alkali, poured into a vessel filled with this gas, is neutralized. 3. Water impregnated with this gas is strongly sub-acid. 4. It neutralizes alkalis, and causes them to crystallize.

It remains at present to examine the properties of this acid gas.

A. It is unfit for respiration. History informs us that two slaves whom Tiberius caused to descend into the Grotto del Cano, were immediately stifled; and two criminals that Peter de Toledo caused to be shut in there, suffered the same fate. The abbé Nollet, who had the courage to respire the vapour, perceived a suffocating sensation, and a slight degree of acidity, which produced coughing and sneezing. Pilatre de Rosier, who presents himself to our notice on all occasions wherein danger was to be faced, caused himself to be fastened by cords fixed under his arms, and descended into the gaseous atmosphere of a back of beer in fermentation. He had scarcely entered into the mephitic before slight prickings obliged him to shut his eyes; a violent suffocation prevented him from respiring; he felt a giddiness, accompanied with those noises which characterize the apoplexy: and when he was drawn up, his sight remained dim for several minutes; the blood had filled the jugulars; his countenance had become purple; and he neither heard nor spoke but with great difficulty: all these symptoms however disappeared by degrees.

It is this gas which produces the many unhappy accidents at the opening of cellars, in places where wine, cyder, or beer are suffered to ferment. Birds plunged into the carbonic acid gas, suddenly perish. The famous Lake of Averno, where Virgil placed the entrance of hell, exhales so large a quantity of carbonic acid, that birds cannot fly over it with impunity. When the waters of Boullidou of Perols are dry, such birds as attempt to quench their thirst in



the closts, are enveloped in the mephitic vapour, and die.

Frogs, plunged in an atmosphere of carbonic acid, live from forty to sixty minutes, by suspending their respiration.

Insects are rendered torpid after a certain time of remaining in this air; but they resume their liveliness the moment they are exposed to the free air.

Bergmann pretended that this acid suffocates by extinguishing irritability: he founds his opinion upon the circumstance of his having taken out the heart of an animal which had died in the carbonic acid, before it was cold, and it exhibited no sign of irritability. The chevalier Landriani has proceeded still further: for he affirms that this gas extinguishes irritability, even when applied to the skin; and has asserted that, by tying a bladder full of this gas to the neck of a fowl, in such a manner that the head only of the animal was in the open air, and the whole body enveloped in the bladder, the fowl immediately perished. The abbé Fontana has repeated and varied this experiment on several animals, none of which died.

The count Morrozzo published experiments made in the presence of Dr. Cigna; the results of which appear to invalidate the consequences of the celebrated Bergmann: but it is to be observed, that the chemist of Turin caused his animals to die only in air vitiated by the death of another animal; and that in this circumstance the nitrogene gas predominates.—See the *Journal de Physique*, tom. xxv. p. 112.

B. The carbonic acid is improper for vegetation. Dr. Priestley having kept the roots of several plants in water impregnated with the carbonic acid, observed that they all perished; and in those instances where plants are observed to vegetate in water or in air which contains this gas, the quantity of gas is very small.

Mr. Senebier has even observed, that plants which are suffered to grow in water slightly acidulated with this gas emit a much larger quantity of oxygenous gas; because, in this case, the acid is decomposed, the carbonaceous

principle combines and is fixed in the vegetable, while the oxigene is thrown off.

I have observed that those fungi which are formed in subterraneous places, are almost totally resolved into carbonic acid; but if these vegetables be gradually exposed to the action of light, the proportion of acid diminishes; while that of the coaly principle augments, and the vegetable becomes coloured. I have pursued these experiments with the greatest care in a coal mine.

C. The carbonic acid is easily dissolved in water. Water impregnated with this acid possesses very valuable medicinal qualities; and several apparatus have been successively invented to facilitate this mixture. The apparatus of Nooth, improved by Parker and Magellan, is one of the most ingenious. On this subject the *Encyclopedia Methodique* may be consulted, article *Acide Mephitique*.

The natural acidulous mineral waters do not differ from these, excepting in consequence of their holding other principles in solution; and they may be perfectly imitated when their analysis is well known. It is absurd to think that art is incapable of imitating nature in the composition of mineral waters. It must be admitted that the processes of nature are absolutely unknown to us, in all the operations which relate to life; and we cannot flatter ourselves with the hope of imitating her in these circumstances. But when the question relates to an operation purely mechanical, or consisting of the solution of certain known principles in water, we can and ought to perform it even still better, as we have the power of varying the doses, and proportioning the efficacy of any artificial mineral water to the purposes to which it is intended to be applied.

D. The carbonic acid gas is heavier than common air. The proportion between these two airs in weight, according to Mr. Kirwan, is 45,69 to 68,74. The proportion, according to the experiments of Mr. Lavoisier, is 48,81 to 69,50.

This considerable weight causes it to occupy the lowest situations; and even gives it the property of being poured out from one vessel to another, so as to displace the atmo-

spheric air. This truly curious phenomenon was observed by Mr. De Sauvages, as may be seen in his Dissertation upon Air, which was crowned in Marseilles in 1750.

It appears to be proved, by sufficient experiments, that the carbonic acid is a combination of carbone, or pure charcoal, and oxigene. 1. The oxides of mercury, when distilled, are reducible without addition, and afford only oxigenous gas; but if a small quantity of charcoal be mixed with the oxide, the product which comes over consists of carbonic gas only, and the weight of the charcoal is diminished.

2. If well-made charcoal be ignited, and plunged into a vessel filled with oxigenous gas, and the vessel be instantly closed, the charcoal burns rapidly, and at last goes out: the product in this experiment is carbonic acid, which may be separated by the known processes; the remainder is a small quantity of oxigenous gas, which may be converted into carbonic acid by the same treatment.

In these experiments I see nothing but charcoal and oxigenous gas; and the consequence deduced is simple and natural.

The proportion of charcoal is to that of oxigene as 12,0288 to 56,687.

When the carbonic acid, in some cases, is obtained by burning hydrogenous gas, it arises from carbone held in solution in this gas. The carbone may even be dissolved in hydrogenous gas, by exposing it to the focus of the burning mirror in the mercurial apparatus, under a glass vessel filled with this gas.

The hydrogenous gas which is extracted from a mixture of sulphuric acid and iron, holds more or less of charcoal in solution; because iron itself contains this substance in a greater or less quantity, as is ascertained by the fine experiments of Messrs. Berthollet, Monge, and Vander Monde.

The alkalis, such as we usually meet with them, contain carbonic acid; and it is this acid which modifies them, and diminishes their energy, at the same time that it communicates to them the property of effervescing.

We may therefore consider alkalis as carbonates with excess of alkali; and it is easy to saturate this superabundant alkali, and to form true crystallizable neutral salts.

## ARTICLE I.

### Carbonate of Pot-ash.

The carbonate of pot-ash was formerly distinguished by the name of Cretaceous Tartar. The method of causing oil of tartar to crystallize, has long been known. Bonhius and Montet have successively shewn these processes: but the simplest consists in exposing an alkaline solution in an atmosphere of the acid gas which is disengaged in the vinous fermentation; the alkali becomes saturated, and forms tetrahedral prismatic crystals terminated by very short four-sided pyramids.

I have several times obtained those crystals in the form of quadrangular prisms, with their extremities cut off slantwise.

This neutral salt no longer possesses the urinous taste of the alkali, but exhibits the penetrating taste of neutral salts, and may be employed in medicine with the greatest success. I have been a witness to its being taken in the dose of one dram (gros) without the least inconvenience.

This salt possesses an advantage beyond the salt of tartar, in being less caustic, and always of the same virtue.

It contains, according to the analysis of Bergmann, twenty parts acid, forty-eight alkali, and thirty-two water, in the quintal.

It does not attract the humidity of the air. I have preserved some of it for several years in a capsule, without any appearance of alteration.

The carbonate of pot-ash is decomposed by silex in a sufficient heat, which occasions a considerable boiling or ebullition. The residue is glass, in which the alkali is in the caustic state. Lime decomposes the carbonate, by uniting to the acid; and acids produce the same effect, by combining with the alkaline bases.



## ARTICLE II.

## Carbonate of Soda.

The denominations of Aerated Mineral Alkali, Cretaceous Soda, &c. have been successively given to this kind of carbonate.

The mineral alkali, in its natural state, contains a greater quantity of carbonic acid than the vegetable; and nothing more is necessary than to dissolve it, and duly evaporate the water, in order to obtain it in crystals.

These crystals are usually rhomboidal octahedrons; and sometimes have the form of rhomboidal laminæ, applied obliquely one upon the other, so that they resemble tiles.

This carbonate effloresces in the air.

One hundred parts contain sixteen parts acid twenty alkali, and sixty-four water.

The affinity of its basis with silica is stronger than that of the carbonate of pot-ash; in consequence of which, the vitrification it produces is more quick and easy.

Lime and the acids decompose it, with the same phenomena which we have observed at the article Carbonate of Pot-ash.

## ARTICLE III.

## Carbonate of Ammoniac.

This salt has been generally known by the name of Concrete Volatile Alkali. It has likewise been distinguished by that of Cretaceous Volatile Alkali, &c.

It may be obtained by distillation from many animal substances. Tobacco affords, likewise, a large proportion; but almost the whole of that which is employed in the arts, and in medicine, is formed by the direct combination of the carbonic acid and ammoniac, or volatile alkali. This combination may be affected—1. By passing the carbonic acid through ammoniac, or the

pure volatile alkali in solution. 2. By exposing ammoniac in an atmosphere of carbonic acid gas. 3. By decomposing the muriate of ammoniac by the neutral salts which contain this acid, such as the carbonate of lime or common chalk. For this purpose, white chalk is taken, and very accurately dried; and then mixed with equal parts of muriate of ammoniac, or common sal ammoniac in fine powder. This mixture is put into a retort, and distilled; the ammoniac and the carbonic acid being disengaged from their bases, and reduced into vapours, combine together, and are deposited on the sides of the receiver, where they form a stratum more or less thick.

The crystallization of this carbonate appeared to me to be that of a four-sided prism, terminated by a dihedral summit.

The carbonate has less smell than the ammoniac; it is very soluble in water. Cold water dissolves its own weight of this salt, at the temperature of sixty degrees of Fahrenheit.

One hundred grains of this salt contain forty-five parts acid, forty-three alkali, and twelve water, according to Bergmann.

Most acids decompose it, and displace the carbonic acid.

## CHAPTER II.

### *Concerning the Sulphuric Acid.*

**SULPHUR**, like every other combustible substance, cannot be burnt but by virtue of the oxygenous gas which combines with it.

The most usual phenomena which accompany this combustion are, a blue flame, a whitish and suffocating vapour, and a strong, penetrating, and disagreeable smell.

The results of this combination vary according to the proportion in which these two principles enter into this same combination.

The sulphureous or the sulphuric acid may be at pleasure obtained from sublimed sulphur, or from crude sulphur, accordingly as a greater or less quantity of oxigene is combined with the sulphur, by means of combustion.

When the current of air which maintains the combustion is rapid, the sulphur is carried, and deposited without any apparent alteration, into the internal part of the leaden chambers in which the oil of vitriol is made. If the current of air be rendered more moderate, the combination is somewhat more accurate; the sulphur is partly changed, and is deposited in a pellicle upon the surface of the water. This pellicle is flexible like a skin, and may be handled and turned over in the same manner. If the current be still less rapid, and the air be suffered to have a sufficient time to form an accurate combination with the sulphur, the result is sulphureous acid; which acid preserves its gaseous form at the temperature of the atmosphere, and may become liquid like water by the application of cold, according to the fine experiments of Mr. Monge. If the combustion be still slower, and the air be suffered to digest upon the sulphur a longer time, and with greater accuracy, the result is sulphuric acid: this last combination may be facilitated by the mixture of saltpetre, because this substance furnishes oxigene very abundantly.

Numerous experiments which I have made in my manufactory, to economize the saltpetre employed in the fabrication of oil of vitriol, have several times exhibited the results here mentioned.

All the processes which are capable of being adapted for extracting the sulphuric acid, are reducible to—1. The extraction of it from substances which contain it. 2. Its direct formation by the combination of sulphur and oxigene.

In the first case, the sulphures, or vitriolic salts of iron, copper, or zinc, and even those whose bases are clay and lime, according to Newman and Margraff, may be exposed to distillation. But these expensive processes are not very

easy to be carried into execution; and accordingly they have been abandoned, to make room for others of greater simplicity.

In the second case, the oxigene may be presented to the sulphur in two forms; either in the state of gas, or in the concrete state.

1. The combustion of sulphur by oxigenous gas, is performed in large chambers lined with lead. The combustion is facilitated by mixing about one-eighth of a nitrate of pot-ash with the sulphur. The acid vapours which fill the chamber are precipitated against its sides, and the condensation is facilitated by a stratum of water disposed on the bottom of the chamber. In some manufactories in Holland, this combustion is performed in large glass balloons with large mouths, and the vapours are precipitated upon water placed at the bottom.

In both cases, when the water is sufficiently impregnated with acid, it is concentrated in leaden boilers, and rectified in glass retorts, to render it white, and to concentrate it sufficiently for the purposes of trade. The acid, when of a due strength, indicates sixty six degrees, according to the acrometer of Mr. Baumé; and when it has not been carried to this degree, it is unfit for most of the uses for which it is intended. It cannot, for example, be employed in dissolving indigo; for the small quantity of nitric acid which it contains, unites with the blue of the indigo, and forms a green colour. I have ascertained this phenomenon by very accurate experiments; and I have been a witness to the failing of colours, and the loss of stuffs, in consequence of the imperfection of the acid.

2. When the oxigene in the concrete state is presented to the sulphur, it is then in combination with other bodies, which it abandons to unite with this last. This happens when the nitric acid is distilled from sulphur. Forty-eight ounces of this acid, at thirty-six degrees, distilled from two ounces of sulphur, afforded near four ounces of good sulphuric acid. This fact was known to Matte Lafaveur: but I pointed out all the phenomena and circumstances of the operation in 1781.



Sulphur may likewise be converted into sulphuric acid by means of the oxygenated muriatic acid.—*Encyclopédie Méthodique*, tom. i. p. 370.

The sulphuric acid which is found disengaged in some places in Italy, appears likewise to arise from the combustion of sulphur. Baldassari has observed it in this state in a hollow grotto, in the midst of a mass of incrustations deposited by the baths of Saint Philip, in Tuscany. He asserts that a sulphureous vapour continually arises in this grotto. He likewise found sulphureous and vitriolic effervescences at St Albino, near mount Pulciano, and at the lakes of Travale, where he observed the branches of a tree covered with concretions of sulphur and the oil of vitriol.—*Journal de Physique*, t. vii. p. 395.

O. Vandelli relates that, in the environs of Sienna and Viterbo, sulphuric acid is sometimes found dissolved in water. Mr. (the commander) De Dolomieu affirms that he found it pure and crystallized in a grotto of mount Etna, from which sulphur was formerly obtained.

According to a first experiment of Mr. Berthollet, sixty-nine parts of sulphur with thirty one parts of oxygen formed one hundred parts of sulphuric acid; and, according to a second experiment, seventy-two of sulphur and twenty-eight of oxygen formed one hundred parts of dry acid.

The various degrees of concentration of the sulphuric acid have caused it to be distinguished by different names, under which it is known in commerce. Hence the denominations of Spirit of Vitriol, Oil of Vitriol, and Glacial Oil of Vitriol, to express its degrees of concentration.

The sulphuric acid is capable of passing to the concrete state by the impression of intense cold. This congelation is a phenomenon long since known. Kunckel and Bohn have spoken of it; and Boerhaave says expressly, “*Oleum vitrioli, summâ arte purissimum, summo frigore hiberno in glebas solidescit perspicuas; sed, statim ac acuties frigoris retunditor, liquefit et diffluit.*”——We are indebted to the Duke D’Ayen for some very valuable experiments upon the congelation of this acid; and Mr. De Morveau repeated them with equal success in 1782, and proved

that this congelation may be effected at a degree of cold considerably less than what had been mentioned\*.

I have already several times obtained beautiful crystals of sulphuric acid in flattened hexahedral prisms, terminated by an hexahedral pyramid; and my experiments have enabled me to conclude—1. That the very concentrated acid crystallizes more difficultly than that whose density lies between sixty-three and sixty-five. 2. That the proper degree of cold is from 1 to 3 degrees below 0 of Reaumur. The detail of my experiments may be seen in the volume of the Academy of Sciences of Paris for the year 1784.

The characters of the sulphuric acid are the following:

1. It is unctuous and fat to the touch, which has occasioned it to obtain the very improper name of Oil of Vitriol.

2. It weighs one ounce and seven gros in a bottle containing one ounce of distilled water.

3. It produces heat, when mixed with water, to such a degree as to exceed that of boiling water. If one end of a tube of glass be closed, and water poured into it, and the closed end of this tube be plunged into water, the water in the tube may be made to boil by pouring sulphuric acid into the external water which surrounds the tube.

4. It seizes with great avidity all inflammable substances; and it is blackened and decomposed by this combination.

Stahl supposed the sulphuric acid to be the universal acid. He founded this opinion more especially upon the circumstance, that cloths soaked in a solution of alkali, and exposed to the air attracted an acid which combined with the alkali; and formed a neutral salt, by him supposed to be of the nature of sulphate of pot-ash, or vitriolated tartar. Subsequent and more accurate experiments have shewn that this aerial acid was the carbonic; and the present state of our knowledge is such as permits

\* See also the experiments of Mr. Kier, and the late experiments of Mr. Cavendish on the congelation of acids, in the Philosophical Transactions.

us still less than ever to believe in the existence of an universal acid.

## ARTICLE I.

*Sulphate of Pot-ash.*

The sulphate of pot-ash is described indifferently under the names of Arcanum Duplicatum, Sal de Duobus, Vitriolated Tartar, Vitriol of Pot-ash, &c.

This salt crystallizes in hexahedral prisms, terminating in hexahedral pyramids, with triangular faces.

It has a lively and penetrating taste, and melts difficultly in the mouth.

It decrepitates on hot coals, becomes red-hot before it fuses, and is volatilized without decomposition.

It is soluble in sixteen parts of cold water, at the temperature of 60 degrees of Fahrenheit: and boiling water dissolves one-fifth of its weight.

100 grains contain 30.21 acid, 64.61 alkali, and 5.18 water. Most of the sulphate of pot-ash used in medicine is formed by the direct combination of the sulphuric acid and pot-ash, or the vegetable alkali: but that which is met with in commerce is produced in the distillation of aqua fortis, by the sulphuric acid: this has the form of beautiful crystals, and is sold in the Comtat Venaissin at forty or fifty livres the quintal. The analysis of tobacco has likewise afforded me this sulphate.

Mr. Baumé proved to the Academy, in 1760, that the nitric acid, assisted by heat, is capable of decomposing the sulphate of pot-ash. Mr. Cornette afterwards shewed that the muriatic acid possesses the same virtue; and I shewed, in 1780, that this acid may be displaced by the nitric acid, without the assistance of heat; though the sulphuric acid resumes its place when the solution is concentrated by heat.

## ARTICLE II.

*Sulphate of Soda.*

This combination of the sulphuric acid and soda is still known under the names of Glauber's Salt, Sal Admirabile,

Vitriol of Soda, &c. This salt crystallizes in rectangular octahedrons, of a prismatic or cuneiform figure, of which the two pyramids are truncated near their basis.

It has a very bitter taste, and easily dissolves in the mouth.

It swells up upon heated coals, and boils, in consequence of the dissipation of its water of crystallization. After this water has been dispersed, there remains only a white powder, difficult of fusion, which is volatilized without decomposition by a strong heat.

By exposure to the air, it effervesces, loses its transparency, and is reduced to a fine powder.

Three parts of water, at 60 degrees of Fahrenheit's thermometer, dissolved one part of this salt; but boiling water dissolves its own weight.

100 grains of sulphate of soda contain 14 acid, 22 alkali and 64 water.

It is formed by the direct combination of the two principles which contain it; but the tamarix gallica, which grows on the sea coasts, contains so large a quantity, that it may be extracted to advantage. Nothing more is necessary for this purpose, than to burn the plant, and lixiviate the ashes. That salt which is sold in the south of France, in fine crystals, is prepared in this manner. It is very pure, and the price does not exceed thirty or thirty-five livres the quintal. This sulphate is likewise formed in our laboratories when we decompose the muriate of soda, or common salt, by the sulphuric acid.

Pot-ash dissolved by heat in a solution of sulphate of soda, precipitates the soda, and takes its place. See my Chemical Memoirs.

### ARTICLE III.

#### *Sulphate of Ammoniac.*

The sulphate of ammoniac, commonly known by the name of Glauber's Secret Ammoniacal Salt, is very bitter.

It crystallizes in long flattened prisms with six sides, terminated by six-sided pyramids.



It cannot be obtained in well-formed crystals but by insensible evaporation.

It slightly attracts the humidity of the air.

It liquefies by a gentle heat, and rises over a moderate fire.

Two parts of cold water dissolve one of this salt; and boiling water dissolves its own weight, according to Fourcroy. The fixed alkalis, barytes, and lime, disengage the ammoniac from it.

The nitric and muriatic acids disengage the sulphuric acid.

The different substances of which we have treated are of considerable use in the arts and medicine.

The sulphureous acid is employed in whitening silk, and giving it a degree of lustre. Stahl had even combined it with alkali, and formed the salt so well known under the name of Stahl's Sulphureous Salt. This combination passes quickly to the state of sulphate, if it be left exposed to the air; as it speedily absorbs the oxygen which is wanting for that purpose.

The principal use of the sulphuric acid is in dying, in which art it serves to dissolve indigo, and carry it in a state of extreme division upon the stuffs to be dyed; it is likewise used by the manufacturers of Indiens, or silk and stuff mixtures, to carry off the preparation of these goods, wherein lime is used. The chemist makes great use of this acid in his analyses; and to separate other acids from their combination, such as the carbonic, the nitric, and the muriatic acids.

The sulphate of pot-ash is known in medicine as an alterative, and is used in cases of lacteous coagulations. It is given in the dose of a few grains, and is even purgative in a greater dose.

The sulphate of soda is an effectual purgative in the dose of from four to eight gros, or drams. For this purpose it is dissolved in a pint of water.

## CHAPTER III.

*Concerning the Nitric Acid.*

THE nitric acid, called Aqua Fortis in commerce, is lighter than the sulphuric. It usually has a yellow colour, a strong and disagreeable smell, and emits red vapours. It gives a yellow colour to the skin, to silk, and to almost all animal substances with which it may come in contact. It dissolves and speedily corrodes iron, copper, zinc, &c. with the escape of a cloud of red vapours during the whole time its action lasts. It entirely destroys the colour of violets, which it reddens. It unites to water with facility; and the mixture assumes a green colour, which disappears when still further diluted.

This acid has been no where found in a disengaged state. It always exists in a state of combination; and it is from these combinations that the art of chemistry extracts it, to apply to our uses. The nitrate of pot-ash, or common nitre, is the combination which is best known, and is likewise that from which we usually extract the nitric acid.

The process used in commerce to make aqua fortis, consists in mixing one part of saltpetre with two or three parts of red bolar earth. This mixture is put into coated retorts, disposed in a gallery or long furnace, to each of which is adapted a receiver. The first vapour which arises in the distillation is nothing but water, which is suffered to escape at the place of juncture, before the luting: and when the red vapours begin to appear, the phlegm which is condensed in the receiver is poured out; and the receiver, being replaced, is carefully luted to the neck of the retort. The vapours which are condensed, form at first a greenish liquor: this colour disappears insensibly, and is replaced by another which is more or less yellow. Some chemists, more especially Mr. Baumé, were of opinion that the

earth acted upon the saltpetre by virtue of the sulphuric acid it contains. But not to mention that this principle does not exist in all the earths made use of, as Messrs. Macquer, De Morveau, and Scheele have proved, we know that pulverized flints equally produce the decomposition of saltpetre. I am therefore of opinion that the effect of these earths upon the salt ought to be referred to the very evident affinity of the alkali to the siliceous, which is a principal component part; and more especially to the slight degree of adhesion which exists between the constituent principles of nitrate of pot-ash.

We decompose saltpetre in our laboratories by means of the sulphuric acid. Very pure nitrate of pot-ash is taken, and introduced into a tubulated retort, placed in a sand bath, with a receiver adapted. All the places of junction are carefully luted; and as much sulphuric acid as amounts to half the weight of the salt is poured through the tubulure; and the distillation is proceeded upon. Care is taken to fit a tube into the tubulure of the receiver; the other end of which is plunged into water, to condense the vapours, and to remove all fear of an explosion.

Instead of employing the sulphuric acid, we may substitute the sulphate of iron, and mix it with saltpetre in equal parts. In this case, the residue of the distillation, when well washed, forms the mild earth of vitriol made use of to polish glass.

Stahl and Kunckel have spoken of a very penetrating aqua fortis, of a blue colour, obtained by the distillation of nitre with arsenic.

Whatever precaution is taken in the purification of the saltpetre, and however great the attention may be which is bestowed upon its distillation, the nitric acid is always impregnated with some foreign acid, either the sulphuric or muriatic, from which it requires to be purified. It is cleared of the first by redistilling it upon very pure saltpetre, which retains the small quantity of sulphuric acid that may exist in the mixture. It is deprived of the second by pouring into it a few drops of a solution of nitrate of silver. The muriatic acid combines

with the silver, and is precipitated with it in the form of an insoluble salt. The fluid is then suffered to remain at rest, and is afterwards decanted from the precipitate or deposition. This acid, so purified, is known under the name of Aqua Fortis for Parting, Precipitated Nitrous Acid, Pure Nitric Acid, &c.

Stahl had considered the nitric acid as a modification of the sulphuric, produced by its combination with an inflammable principle. This opinion has been supported by several new facts, in a dissertation of Mr. Pietsh, crowned by the Academy of Berlin in 1749.

The experiments of the celebrated Hales led him still nearer to this conclusion, as his manipulations were successively employed upon the two constituent principles of the nitric acid. This celebrated philosopher had obtained ninety cubic inches of air from half a cubic inch of nitre; and he proceeded no further in his conclusions, than to assert that this air is the principal cause of the explosions of nitre.

The same philosopher relates that the pyrites of Walton, treated with equal quantities of spirit of nitre and water, produce an air which has the property of absorbing the fresh air, which may be made to enter the vessel. This great man, therefore, extracted successively the two principles of the nitric acid; and these capital experiments put Dr. Priestley in the road to the discoveries he has since made.

It was not however until the year 1776, that the analysis of the nitric acid was well known. Mr. Lavoisier, by distilling this acid from mercury, and receiving the several products in the pneumato-chemical apparatus, has proved that the nitric acid, whose specific gravity is to that of distilled water as 131607 to 100000, contains—

	oz.	gros.	grains.
Nitrous gas	1	7	$51\frac{1}{4}$
Oxygenous gas	1	7	$7\frac{1}{2}$
Water	13	—	—

By combining these three principles together the decomposed acid was regenerated.



The action of the nitric acid on most inflammable matters, consists in nothing more than a continual decomposition of this acid.

If the nitric acid be poured upon iron, copper, or zinc, these metals are instantly attacked with a strong effervescence; and a considerable disengagement of vapours takes place, which become of a red colour by their combination with the atmospheric air, but which may be retained and collected in a state of gas in the hydro-pneumatic apparatus. In all these cases the metals are strongly oxidized.

The nitric acid, when mixed with oils, renders them thick and black, converts them into charcoal, or inflames them, accordingly as the acid is more or less concentrated, or in a greater or less quantity.

If very concentrated nitric acid be put into an apothecary's phial, and be poured upon charcoal in an impalpable powder, and very dry, it sets it on fire instantly, at the same time that carbonic acid and nitroge gas are disengaged.

The various acids which are obtained by the digestion of the nitric acid on certain substances, such as the oxalic acid, or acid of sugar, the arsenical acid, &c. owe their existence merely to the decomposition of the nitric acid, the oxigene of which is fixed in combination with the bodies upon which the acid is distilled. The facility with which this acid is decomposed, renders it one of the most active because the action of acids upon most bodies is a consequence of their own proper decomposition.

The characters of nitrous gas, which is extracted by the decomposition of the acid, are—1. It is invisible, or perfectly transparent. 2. Its specific gravity is rather less than that of atmospherical air. 3. It is unfit for respiration, though the abbé Fontana pretends that he respired it without danger. 4. It does not maintain combustion. 5. It is not acid, according to the experiments of the Duke de Chaulnes. 6. It combines with oxigene, and reproduces the nitric acid.

But what is the nature of this nitrous gas? It was at first pretended that it consists of the nitric acid saturated

with phlogiston. This system ought to have been abandoned as soon as it was proved that the nitric acid deposited its oxigene upon the bodies on which it acted; and that the nitrous gas was less in weight than the acid made use of. A capital experiment of Mr. Cavendish has thrown the greatest light on the subject. This chemist having introduced into a tube of glass seven parts of oxigenous gas obtained without nitrous acid, and three parts of nitrogene gas; or, by estimating these quantities in weight, ten parts of nitrogene to twenty-six of oxigene—and having caused the electric spark to pass through this mixture, perceived that its volume or bulk was greatly diminished, and succeeded in converting it into nitric acid. It may be presumed, from his experiment, that the acid is a combination of seven parts of oxigene, and three of nitrogene. These proportions constitute the ordinary nitric acid; but when a portion of its oxigene is taken away, it passes to the state of nitrous gas; so that nitrous gas is a combination of nitrogene gas, with a small quantity of oxigene.

Nitrous gas may be decomposed by exposing it to a solution of the sulphure of pot-ash, or hepar of sulphur: the oxigene gas unites to the sulphur, and forms sulphuric acid while the nitrogene gas remains behind in a state of purity.

Nitrous gas may likewise be decomposed by means of pyrophorus, which burns in this air, and absorbs the oxigenous gas.

The electric spark has likewise the property of decomposing nitrous gas. Mr. Van Marum has observed that three cubic inches of the nitrous gas are reduced by electricity to one cubic inch and three quarters; and that this residue no longer possessed any property of nitrous gas. Lastly, according to the experiments of Mr. Lavoisier, one hundred grains of nitrous gas contain thirty-two parts nitrogene, and sixty-eight parts oxigene: according to the same chemist, one hundred grains of nitric acid contain seventy-nine and a half oxigene and twenty and a half nitrogene; and this is the reason why nitrous gas should be employed in a less portion than nitrogene gas, to

combine with the oxigene gas, and form the nitric acid.

These ideas upon the composition of the nitrous acid, appear to be confirmed by the repeated proofs we now have of the necessity of causing substances, which afford much nitrogene gas, to be presented to the oxigene gas, in order to obtain nitric acid.

The several states of the nitric acid may be clearly explained according to this theory:—1. The fuming nitrous acid is that in which the oxigene does not exist in a sufficient proportion; and we may render the whitest and the most saturated nitric acid fuming and ruddy, by depriving it of a part of its oxigene by means of metals, oils, inflammable substances, &c. or even by disengaging the oxigene by the simple exposition of the acid to the light of the sun, according to the valuable experiments of Mr. Berthollet.

The property which nitrous gas possesses, of absorbing oxigene to form the nitric acid, has caused it to be employed to determine the proportion of oxigene in the composition which forms our atmosphere. The abbé Fontana has constructed, on these principles, an ingenious eudiometer, the description and manner of using which may be seen in the first volume of Dr. Ingenhoufz's Experiments upon Vegetables.

Mr. Berthollet has very justly observed, that this eudiometer is inaccurate, or productive of deception—1. Because it is difficult to obtain nitrous gas constantly formed of the same proportions of nitrogene gas and oxigene; for they vary, not only according to the nature of the substances upon which the nitric acid is decomposed, but likewise accordingly as the solution of any given substance by the acid is made with greater or less rapidity. If the acid be decomposed upon a volatile oil, nothing but nitrogene gas can be obtained; if the acid act upon iron, and it be much concentrated, nitrogene gas only will be obtained, as I have observed, &c. 2. The nitric acid which is formed by the union of nitrous gas and oxigene, dissolves a greater or less quantity of nitrous gas according to the temperature, the quality of the air which

is tried, the size of the eudiometer, &c. so that the diminution varies in proportion to the greater or less quantity of nitrous gas obtained by the nitric acid which is formed: consequently the diminution ought to be greater in winter than in summer, &c.

According to the experiments of Mr. Lavoisier, four parts of oxygenous gas are sufficient to saturate seven parts and one third of nitrous gas; whereas it is found that nearly sixteen parts of atmospheric air are required to produce the same effect: whence this celebrated chemist has concluded, that the air of the atmosphere does not in general contain more than one-fourth of oxygenous or respirable gas. Repeated experiments at Montpellier, upon the same principle, have convinced me that twelve or thirteen parts of atmospheric air are constantly sufficient to saturate seven parts and one-third of nitrous gas.

These experiments shew, to a certain degree of accuracy, the proportion in which vital air exists in the air which we respire; but they do not give us any information respecting the noxious gases which, when mixed with the atmospheric air, alter it, and render it unwholesome. This observation very much curtails the use of this instrument.

The combination of the oxygenous and nitrous gases always leaves an æriform residue, which Mr. Lavoisier estimated at about one thirty-fourth of the whole volume: it arises from the mixture of the foreign gaseous substances, which more or less affect the purity of the gases made use of.

## ARTICLE I.

### Nitrate of Pot-ash.

The nitric acid, combined with pot-ash, forms the salt so well known under the names of Nitre, Saltpetre, Nitre of pot-ash, &c.

This neutral salt is rarely the product of any direct combination of its two constituent parts. It is found ready formed in certain places; and in this manner it is



that the whole of the nitre employed in the arts is obtained.

In the Indies, it effloresces on the surface of uncultivated grounds. The inhabitants lixivate these earths with water, which they afterwards boil and crySTALLIZE in earthen pots. Mr. Dombey has observed a great quantity of saltpetre near Lima, upon earths which serve for pasture, and which produce only gramineous plants. Mr. Albot Dillon, in his travels into Spain, relates that one-third of all the grounds, and in the southern parts of that kingdom even the dust of the roads, contain saltpetre.

Saltpetre is extracted in France from the ruins and plaster of old houses.

This salt exists ready formed in vegetables, such as parietaria and bugloss, &c. and one of my pupils, Mr. Virenque, has proved that it is produced in all extracts which are capable of fermenting.

The fermentation of saltpetre may be favoured, by causing certain circumstances to concur which are of advantage to its formation.

In the North of Europe, the saltpetre-beds are formed with lime, ashes, earth of uncultivated grounds, and straw, which are stratified, and watered with urine, dunghill-water, and mother waters. These beds are defended by a covering of heath or broom. In the year 1775, the King caused a prize to be proposed by the Royal Academy of Sciences at Paris, to discover a method of increasing the product of saltpetre in France, and to relieve the people from the obligation of permitting the saltpetre-makers to examine their cellars, in order to discover and carry away saltpetre earths. Several Memoirs were offered on the subject, which the Academy united into a single volume; and these have added to our knowledge, by instructing us more especially concerning the nature of the matters which favour the formation of nitre. It was known, for example, long since, that nitre is formed in preference near habitations, or in earths, impregnated with animal products: it was likewise known that, in general, the alkaline basis was afforded by the concurrence

of a vegetable fermentation. Mr. Thouvenel, whose memoir was crowned, has proved that the gas which is disengaged by putrefaction, is necessary for the formation of nitre; that blood, and next to it, urine, were the animal parts which were the most favourable to its formation; that the most minutely divided and the lightest earths were the most proper for nitrification; that the current of air must be properly managed, to fix upon these earths the nitric acid which is formed, &c.

It seems to me that Becher possessed a considerably accurate knowledge of the formation of nitre, as appears from the following passages:

“Hæc enim (vermes, muscæ, serpentes) putrefacta in terram abeunt prorsus nitrosam; ex qua etiam communi modo nitrum copiosum parari potest, sola elixatione cum aqua communi.”—*Phys. Subt. lib. i. S. V. t. i. p. 286.*

“Sed et ipsum nitrum necdum finis ultimus putrefactionis est; nam cum ejusdem partes igneæ separantur, relinquæ in terram abeunt prorsum puram & insipidam, sed singulari magnetismo præditam novum spiritum aëreum attrahendi, rursusque nitrum fiendi.”—*Phys. Subt. S. V. t. i. p. 292.*

From all the discoveries and observations which have been hitherto made, it follows that, in order to establish artificial nitre beds, it is necessary that animal putrefaction and vegetable fermentation should concur. The nitrogen gas, in its disengagement from the animal substances, combines with the oxigene, and forms the acid, which again unites with the alkali, whose formation is favoured by the vegetable decomposition.

When the manufacturer is in possession of saltpetre grounds, whether by the simple operations of nature or by the assistance of art, the saltpetre is extracted by the lixiviation of these earths; which lixivium is afterwards concentrated, and made to crystallize. In proportion as the evaporation goes forward, the marine salt, which almost always accompanies the formation of nitre, is precipitated. This is taken out with ladles, and set to drain in baskets placed over the boilers.

As a great part of the nitre has an earthy basis, and requires to be furnished with an alkaline basis to cause it to crystallize, this purpose is accomplished either by mixing ashes with the saltpetre earths, or by adding an alkali ready formed to the lixivium itself.

Nitre obtained by this first operation is never pure, but contains sea-salt, and an extractive and colouring principle, from which it must be cleared. For this purpose it is dissolved in fresh water, which is evaporated; and to which bullocks blood may be added, to clarify the solution. The nitre obtained by the second manipulation is known by the name of Nitre of the Second Boiling. If recourse be had to a third operation to purify it, it is then called Nitre of the Third Boiling.

The purified nitrate of pot-ash is employed in delicate operations, such as the manufacture of gunpowder, the preparation of aqua fortis for parting, and the solution of mercury, &c. The saltpetre of the first boiling is used in those works where aqua fortis is made for the dyers. It affords a nitro-muriatic acid, which is capable of dissolving tin by itself.

The nitrate of pot-ash crystallizes in prismatic octahedrons, which almost always represent six-sided flattened prisms, terminated by dihedral summits.

It has a penetrating taste followed by a sensation of coldness.

It is fusible upon ignited coals; and in this case its acid is decomposed. The oxigene unites with the carbone and forms the carbonic acid; the nitrogene gas and the water are dissipated; and it is this mixture of principles which has been known under the name of Clyffus of Nitre.

The distillation of the nitrate of pot-ash affords twelve thousand cubic inches of oxigenous gas for each pound of the salt.

Seven parts of water dissolve one of nitre, at sixty degrees of Fahrenheit; and boiling water dissolves its own weight of this salt.

One hundred grains of the crystals of nitre contain thirty acid, sixty-three alkali, and seven water.

When a mixture of equal parts of nitre and sulphur are thrown into a red-hot crucible, a saline substance is obtained, which was formerly called *Sal Polychrest* of Glaſer, and which has ſince been conſidered as Sulphate of Pot-aſh. If nitre be fuſed, and a few pinches of ſulphur be thrown upon this ſalt in fuſion, and the whole be afterwards poured out or caſt into plates, it forms a ſalt known by the name of *Crystal Mineral*.

A mixture of ſeventy-five parts of nitre, nine and a half of ſulphur, and fifteen and a half of charcoal, forms gunpowder. This mixture is triturated from ten to fifteen hours, care being taken to moiſten it from time to time. This trituration is uſually performed by pounding mills, whoſe peſtles and mortars are of wood. In order to give the powder the form proper to granulate it, it is paſſed through ſieves of ſkin, whoſe perforations are of various ſizes. The grained powder is then ſifted, to ſeparate the duſt, and it is afterwards carried to the drying-houſe. Gunpowder for artillery, or cannon-powder, receives no other preparation; but it is neceſſary to glaze the powder which is intended for fowling. This laſt preparation is effected by putting it into a kind of caſk which turns on an axis, and by whoſe movement the angles of the grains are broken, and their ſurfaces poliſhed. We are indebted to Mr. Beaumé and the chevalier Darcy for a ſeries of experiments, in which they have proved—

1. That good gunpowder cannot be made without ſulphur.

2. That charcoal is likewise indispensably neceſſary.

3. That the quality of gunpowder depends, *cæteris paribus*, upon the accuracy with which the mixture is made.

4. That the effect of powder is greater when ſimply dried than when it is granulated.

The effect of gunpowder depends upon the rapid decomposition which is made in an inſtant of a conſiderable maſs of nitre, and the ſudden formation of thoſe gaſes which are the immediate produã. Bernoulli, in the laſt century, aſcertained the development of air by



the deflagration of gunpowder: he placed four grains of powder in a recurved tube of glass, plunged the tube in water, and set fire to the gunpowder by means of the burning-glass; after the combustion the interior air occupied a larger space, so that the space abandoned by the water was such as would have contained two hundred grains of gunpowder.—Hist. de l'Académie des Sciences de Paris, 1696, t. ii. Memoire de M. Varignon sur le Feu et la Flamme.

The fulminating powder, which is made by the mixture and trituration of three parts of nitre, two of salt of tartar, and one of sulphur, produces effects still more terrible. In order to obtain the full effect, it is exposed in a ladle to a gentle heat; the mixture melts, a sulphureous blue flame appears, and the explosion takes place. Care must be taken to give neither too strong nor too slight a degree of heat. In either case, the combustion of the principles takes place separately, and without explosion.

## ARTICLE II.

### Nitrate of Soda.

This salt has received the name of Cubic Nitre on account of its form; but this denomination is not exact, because it affects a figure constantly rhomboidal.

It has a cool, bitter taste.

It slightly attracts the humidity of the air.

Cold water, at sixty degrees of Fahrenheit's thermometer, dissolves one-third of its weight; and hot water scarcely dissolves more.

It fuses upon burning coals with a yellow colour; whereas common nitre affords a white flame, according to Margraff—24 Dissert. sur le Sel Commun, t. ii. p. 343.

100 grains of this salt contain 28.80 acid, 50.09 alkali, and 21.11 water.

It is almost always the product of art.

## ARTICLE III.

## Nitrate of Ammoniac.

The vapours of ammoniac, or volatile alkali, being brought into contact with those of the nitrous acid, combine with them, and form a white and thick cloud, which slowly subsides.

But when the acid is directly united to the alkali, the result is a salt, which has a cool, bitter, and urinous taste.

Mr. De Lisle pretends that it crystallizes in beautiful needles, similar to those of sulphate of pot-ash.

These crystals cannot be obtained but by a very slow evaporation.

When this salt is exposed to the fire, it liquefies, emits aqueous vapours, dries, and detonates.

Mr. Berthollet has analysed all the results of this operation, and has drawn from them a new proof of the truth of the principles which he has established with regard to ammoniac.

## CHAPTER IV.

*Concerning the Muriatic Acid.*

THIS acid is generally known by the name of Marine Acid, and it is still distinguished among artificers by the name of Spirit of Salt.

It is lighter than the two preceding acids; it has a strong penetrating smell, resembling that of saffron, but infinitely more pungent; it emits white vapours when it is concentrated; it precipitates silver from its solution in the form of an insoluble salt, &c. This acid has no where been

found disengaged; and, to obtain it in this state, it is necessary to disengage it from its combinations. Common salt is usually employed for this purpose.

The spirit of salt of commerce is obtained by a process little differing from that which is used in the extraction of aqua fortis. But as this acid adheres more strongly to its basis, the product is very weak, and only part of the marine salt is decomposed.

Flints pulverized and mixed with this salt, do not separate the acid. Ten pounds of flints in powder, treated by a violent fire with two pounds of the salt, did not afford me any other product than a mass of the colour of litharge. The fumes were not perceptibly acid. If clay, which has once served to decompose marine salt, be mixed with a new quantity of the same salt, it will not decompose an atom of it, even though the mixture be moistened and formed into a paste. These experiments have been several times repeated in my manufactory, and have constantly exhibited the same results.

The sulphate of iron, or martial vitriol, which so easily disengages the nitric acid, decomposes marine salt; but very imperfectly.

The impure soda known in France by the name of Blanquette, and in which my analysis has exhibited twenty-one pounds of common salt out of twenty-five, scarcely affords any muriatic acid when it is distilled with the sulphuric acid; but it affords abundance of sulphureous acid. Mr. Berard, director of my manufactory attributed these results to the coal contained in this soda, which decomposed the sulphuric acid. He therefore calcined the blanquette to destroy the charcoal: and then he found he could treat it in the same manner as common salt, and with the same success.

The sulphuric acid is usually employed to decompose marine salt. My method of proceeding consists in drying the marine salt, pounding it, and putting it into a tubulated retort placed upon a sand bath. A receiver is adapted to the retort, and afterwards two bottles, after the manner of Woulfe, in which I distribute a weight of distilled water equal to that of the marine salt made

use of. The joinings of the vessels are then luted, but with the greatest caution; and when the apparatus is thus fitted up, a quantity of sulphuric acid is poured through the tubulure equal to half the weight of the salt. A considerable ebullition is immediately excited; and when this effervescence is slackened, the retort is gradually heated, and the mixture made to boil.

The acid is disengaged in the state of gas; and mixes rapidly with the water, in which it produces a considerable degree of heat.

The water of the first bottle is usually saturated with the acid gas, and forms a very concentrated and fuming acid; and though the second is weaker, it may be carried to any desired degree of concentration, by impregnating it with a new quantity of the gas.

The ancient chemists were divided respecting the nature of the muriatic acid. Becher supposed it to be the sulphuric acid modified by his mercurial earth.

This acid is susceptible of combining with an additional dose of oxigene; and, what is very extraordinary, it becomes more volatile in consequence of this additional quantity; whereas the other acids appear to acquire a greater degree of fixity in the same circumstances. It may even be said, that its acid virtues become weaker in this case, since its affinities with alkalis diminish; and it is so far from reddening blue vegetable colours, that it destroys them.

Another phenomenon not less interesting, which is presented to us by this new combination, is, that though the muriatic acid seizes the oxigene with avidity, yet it contracts so weak a union with it, that it yields it to almost all bodies, and the mere action of light alone is sufficient to disengage it.

It is to Scheele that we are indebted for the discovery of the oxygenated muriatic acid. He formed it in the year 1774, by employing the muriatic acid as a solvent for manganese. He perceived that a gas was disengaged, which possessed the distinctive smell of aqua regia; and he was of opinion that in this case the muriatic acid abandoned its phlogiston to the manganese; in consequence



of which notion he called it the Dephlogisticated Marine Acid. He took notice of the principal and truly astonishing properties of this new substance; and all chemists since his time have thought their attention well employed in examining a substance which exhibits such singular properties.

To attract this acid, I place a large glass alembic of one single piece upon a sand bath. To the alembic I adapt a small receiver; and to the receiver three or four small bottles nearly filled with distilled water, and arranged according to the method of Woulfe. I dispose the receiver and the bottles in a cistern, the places of junction being luted with fat lute, and secured with rags soaked in the lute of lime and white of egg. Lastly, I surround the bottles with pounded ice. When the apparatus is thus disposed, I introduce into the alembic half a pound of manganese of Cavennes, and pour upon it, at several repetitions, three pounds of fuming muriatic acid. The quantity of acid which I pour at once is three ounces; and at each time of pouring a considerable effervescence is excited. I do not pour a new quantity until nothing more comes over into the receivers. This method of proceeding is indispensably necessary, when the operator is desirous of making his process with a definite quantity of the materials. For if too large a quantity of acid be poured at once, it is impossible to restrain the vapours; and the effervescence will throw a portion of the manganese into the receiver. The vapours which are developed by the affusion of muriatic acid are of a greenish yellow colour; and they communicate this colour to the water when they combine with it. When this vapour is concentrated by means of the ice, and the water is saturated with it, it forms a scum at the surface, which is precipitated through the liquid, and resembles a congealed oil. It is necessary to assist the action of the muriatic acid by means of a moderate heat applied to the sand bath. The secure luting of the vessels is also an essential circumstance; for the vapour which might escape is suffocating, and would not permit the chemist to inspect his operation closely. It is easy to discover the place where it escapes through the lutes, by

running a feather dipped in volatile alkali over them; the combination of these vapours instantly forms a white cloud, which renders the place visible where the vapour escapes. An excellent Memoir of Mr. Berthollet, published in the *Annales Chimiques*, may be consulted upon the oxygenated muriatic acid.

The same oxygenated muriatic acid may be obtained by distilling, in a similar apparatus, ten pounds of marine salt, three or four pounds of manganese, and ten pounds of sulphuric acid.

Mr. Reboul has observed that the concrete state of this acid is a crystallization of the acid, which takes place at three degrees of temperature below the freezing point of Reaumur. The forms which have been observed are those of a quadrangular prism truncated very obliquely, and terminated by a lozenge. He has likewise observed hollow hexahedral pyramids on the surface of the liquor.

To make use of the oxygenated acid in the arts, and in order to concentrate a greater quantity in a given volume of water, the vapour is made to pass through a solution of alkali. A white precipitate is at first formed in the liquor; but a short time afterwards the deposition diminishes, and bubbles are disengaged, which are nothing but the carbonic acid. In this case two salts are formed, the oxygenated muriate, and the ordinary muriate. The mere impression of light is sufficient to decompose the former, and convert it into common salt. This lixivium contains, indeed, the oxygenated acid in a stronger proportion. The execrable smell of the acid is much weakened. It may be employed for various uses with the same success, and with great facility; but the effect is very far from corresponding with the quantity of oxygenated acid which enters into this combination, because the virtue of a great part is destroyed by its union with the alkaline basis.

The oxygenated muriatic acid has an excessively strong smell. It acts directly on the larynx, which it stimulates, excites coughing, and produces violent head-aches.

Its taste is sharp and bitter. It speedily destroys the colour of tincture of turnsole. But it appears that the property which most oxygenated substances possess, of

reddening blue colours, arises only from the combination of oxygen with the colouring principles; and that, when this combination is very strong and rapid, the colour is destroyed.

The oxygenated muriatic acid with which a solution of caustic alkali is saturated, affords, by evaporation in vessels secluded from the light, common muriate and oxygenated muriate. This last detonates upon charcoal; is more soluble in hot than in cold water; crystallizes, sometimes in hexahedral laminae, and oftner in rhomboidal plates. These crystals have an argentine brilliancy, like mica. Its taste is faint; and its crystals, when they are dissolved in the mouth, produce a sensation of coolness resembling that of nitre.

Mr. Berthollet has ascertained, by delicate experiments that the oxygenated muriatic acid which exists in the oxygenated muriate of pot-ash, contains more oxygen than an equal weight of oxygenated muriatic acid dissolved in water; and this has led him to consider the oxygenated acid combined in the muriate as being superoxygenated. He considers the common muriatic gas with relation to the oxygenated muriatic gas, the same as the nitrous gas or sulphureous gas with respect to the nitric and sulphuric acids. He pretends that the production of the simple muriate and the oxygenated muriate in the same operation, may be compared to the action of the nitric acid, which in many cases produces nitrate and nitrous gas. Hence he has considered the muriatic acid as a pure radical, which, combined with a greater or less quantity of oxygen, forms either simple muriatic acid gas, or the oxygenated muriatic acid gas.

The oxygenated muriates of soda do not differ from those of pot-ash, but in being more deliquescent and soluble in alcohol, like all the salts of this nature.

The oxygenated muriate of pot-ash gives out its oxygen in the light, and by distillation as soon as the vessel is heated to redness. One hundred grains of this salt afford seventy five cubic inches of oxygenous gas reduced to the temperature of twelve degrees of Reaumur. This air is purer than the others, and may be employed for delicate

experiments the oxygenated muriate of pot-ash, when crystallized, does not trouble the solutions of nitrate of lead, of silver, or of mercury.

M. Berthollet has fabricated gunpowder, by substituting the oxygenated muriate instead of saltpetre. The effects it produced were quadruple. The experiment in the large way, which was made at Essone, is but too well known, by the death of Mr. Le Tors and Mademoiselle Chevrard. This powder exploded the moment the mixture was triturated.

The oxygenated muriatic acid whitens thread and cotton. For this purpose the cotton is boiled in a weak alkaline lixivium; after which the stuff is wrung out, and steeped in the oxygenated acid. Care is taken to move the cloth occasionally in the fluid, and to wring it out. It is then washed in a large quantity of water, to deprive it of the smell with which it is impregnated.

I have applied this known property to the whitening of paper and old prints: by this means they obtained a whiteness which they never before possessed. Common ink disappears by the action of this acid; but printers ink is not attacked by it.

Linen and cotton cloths, and paper, may be bleached by the vapour of the oxygenated marine acid. I have made some experiments in the large way, which have convinced me of the possibility of applying this method to the arts. The Memoir in which I have given an account of my experiments, will be printed in the volume of the Academy of Paris for the year 1787.

The oxygenated muriatic acid thickens oils; and oxides metals to such a degree, that this process may be advantageously used to form verditer.

The oxygenated muriatic acid dissolves metals without effervescence; because its oxigene is sufficient to oxide them without the necessity of the decomposition of water, and consequently of the disengagement of gas.

This acid precipitates mercury from its solutions, and converts it into the state of corrosive sublimate.

It converts sulphur into sulphuric acid, and instantly deprives the very black sulphuric acid of its colour.



When mixed with nitrous gas, it passes to the state of muriatic acid, and converts part of the gas into nitric acid.

When exposed to light, it affords oxygenous gas, and the muriatic acid is regenerated.

The muriatic acid acts very efficaciously upon metallic oxides, merely in consequence of its becoming oxygenated; and in this case it forms with them salts, which are more or less oxygenated.

## ARTICLE I.

### *Muriate of Pot-ash.*

This salt is still distinguished by the name of Febrifuge salt of Sylvius.

It has a disagreeable strong bitter taste.

It crystallizes in cubes, or in tetrahedral prisms.

It decrepitates upon coals; and when urged by a violent heat it fuses, and is volatilized without decomposition.

It requires three times its weight of water, at the temperature of sixty degrees of Fahrenheit, for its solution.

It is subject to scarcely any alteration in the air.

One hundred grains of this salt contain 29.68 acid, 63.47 alkali, and 6.85 water. It is frequently met with, but in small quantities, in the water of the sea, in plaster, in the ashes of tobacco, &c. The existence of this salt in the ashes of tobacco might with justice have surprised me, as I had reason to expect the muriate of soda which is employed in the operation called watering. Was the soda metamorphosed into pot-ash by the vegetable fermentation? This may be determined by direct experiments.

## ARTICLE II.

### *Muriate of Soda.*

The received names of Marine Salt, Common Salt, and Culinary Salt, denote the combination of muriatic acid with soda.

This salt has a penetrating but not bitter taste. It decrepitates on coals, fuses, and is volatilized by the heat of a glass-maker's furnace, without decomposition.

It is soluble in 2.5 times its weight of water, at sixty degrees of Fahrenheit's thermometer.

One hundred grains of this salt contain 33.3 acid, 50 of alkali, and 16.7 of water.

It crystallizes in cubes. Mr. Gmelin has informed us that the salt of the salt lakes in the environs of Sellian on the banks of the Caspian sea, forms cubical and rhomboidal crystals.

Mr. De Lisle observes, that a solution of marine salt, left to insensible evaporation during five years by Mr. Rouelle, had formed regular octahedral crystals resembling those of alum.

Marine salt may be obtained in octahedrons, by pouring fresh urine into a very pure solution of fresh salt. Mr. Berniard is convinced that this addition changed only the form of the salt, without altering its nature.

Common salt is found native in many places. Catalonia, Calabria, Switzerland, Hungary, and Tyrol possess mines, which are more or less abundant. The richest salt mines are those of Wieliczka in Poland. Mr. Berniard has given us a description of them in the *Journal de Physique*; and Mr. Macquart, in his *Essays on Mineralogy*, has added interesting details concerning the working of these mines.

Our salt springs in Lorraine and Franche-comté, and some indications afforded by Bleton, have appeared sufficient motives to Mr. Thouvenel to presume that salt mines exist in our kingdom. This chemist expresses himself in the following manner:

“At the distance of two leagues from Saverne, between the village of Huftenhausen and that of Garbourg, in a lofty mountain called Penssenperch, there are two great reservoirs of salt water; the one to the east, at the head of a large deep and narrow valley, which is called the great Limerthaal; the other to the west, upon the opposite slope, towards Garbourg. They communicate together by five small streams, which are detached from the upper reservoir, and unite in the lower one. From these two salt reservoirs flow two large streams; the upper runs into Franche-comté, and the lower into Lorraine, where they supply the well-known salt works.”

The waters therefore flow to the distance of seventy leagues from the reservoir.

Salt mines appear to owe their origin to the drying up of vast lakes. The shells and madrepores found in the immense mines of Poland are proofs of marine depositions. There are likewise some seas in which the salt is so abundant, that it is deposited at the bottom of the water; as appears from the analysis of the water of the lake Asphaltites, made by Messrs. Macquer and Sage.

This native salt is often coloured; and as in this state it possesses considerable brilliancy, it is called *Sal-gem*. It almost always contains an oxide of iron, which colours it.

As these salt mines are neither sufficiently abundant to supply the wants of the inhabitants of the globe, nor distributed with that uniformity as to permit all nations to have ready recourse to them, it has been found necessary to extract the salt from the water of the sea. The sea does not contain an equal quantity in all climates: Ingenhoufz has shewn us that the northern seas contain less than the southern. Marine salt is so abundant in Egypt, that, according to Hasselquist, a fresh-water spring is a treasure which is secretly transmitted from father to son.

The method of extracting the water of the sea varies according to the climates.

1. In the northern provinces, the salt sands of the sea coasts are washed with the least possible quantity of water, and the salt is obtained by evaporation.—See the description of this process by Mr. Guettard.

2. In very cold countries, salt water is concentrated by freezing, and the residue is evaporated by fire.—See Wallerius.

3. At the salt springs of Lorraine and Franche-comté, the water is pumped up, and suffered to fall upon heaps of thorns, which divide it, and cause a part to evaporate. The farther concentration is effected in boilers.

4. In the southern provinces, at Peccais, at Peyrat, at Cette, and elsewhere, the extraction is begun by separating a certain quantity of water from the general mass of the sea, which is suffered to remain in square spaces, called *Partenemens*. For this purpose it is necessary to

have sluices which may be opened and shut at pleasure, and to form surrounding walls which prevent all communication with the sea, except by means of these gates. It is in the *partenemens* that the water goes through the first stage of evaporation; and when it begins to deposit its salt, it is raised by bucket wheels to other square compartments, called *Tables*, where the evaporation finishes.

The salt is heaped together, to form the *cammelles*; in which state it is left for three years, in order that the deliquescent salts may flow out of it; and, after this interval of time, it is carried to market.

Exertions and enquiries have long since been made to discover a cheap method of decomposing marine salt, to obtain the mineral alkali at a low price, which is of such extensive use in the manufactures of soap, glass, bleaching, &c. The processes hitherto discovered are the following:

1. The nitric acid disengages the muriatic acid, and forms nitrate of soda, which may be easily decomposed by detonation.

2. Pot-ash displaces the soda, even in the cold, as I found by experiment.

3. The sulphuric acid forms sulphate of soda by decomposing the marine salt; the new salt, when heated with charcoal, is destroyed; but a sulphure of soda, or liver of sulphur, is formed, which is difficult to be entirely separated; and this process does not appear to me to be economical. The sulphure may likewise be decomposed by the acetite of barytes, and the soda afterwards obtained by calcination of the acetite of soda.

4. Margraff tried in vain to accomplish this purpose, by means of lime, serpentine, iron, clay, &c. He adds that if common salt be thrown upon lead heated to redness, the salt is decomposed, and muriate of lead is formed.

5. Scheele has pointed out the oxides of lead for the decomposition of common salt. If common salt be mixed with litharge, and made into a paste, the litharge gradually loses its colour, and becomes converted into a white matter, from which the soda may be extracted by washing. It is by processes of this kind that Turner extracts it in England; but this decomposition never appeared to me to



be complete, unless the litharge was employed in a proportion quadruple to that of the salt. I have observed that almost all bodies are capable of alkalizing marine salt, but that the absolute decomposition is very difficult.

6. Barytes decomposes it likewise, according to the experiments of Bergmann.

7. The vegetable acids, combined with lead, may likewise be used to decompose common salt. When these salts are mixed, a decomposition takes place: the muriate of lead falls down; and the vegetable acid, united to the soda, remains in solution. The vegetable acid may be dissipated by evaporation and calcination; and the alkali remains disengaged.

Marine salt is more especially employed at our tables, and in culinary purposes. It removes and corrects the insipidity of our food, and at the same time facilitates digestion. It is used in a large proportion to preserve flesh from putrefaction; but in a small dose it hastens that process, according to the experiments of Pringle, Macbride, Gardane, &c.

### ARTICLE III.

#### *Muriate of Ammoniac.*

Of all the combinations of ammoniac this is the most interesting, and the most generally used. It is known by the name of *Sal Ammoniac*.

This salt may be directly formed by decomposing the muriate of lime by the means of ammoniac, as Mr. Baumé has practised at Paris. But almost all the sal ammoniac which circulates in commerce is brought to us from Egypt, where it is extracted by distillation from foot, by the combustion of the excrements of such animals as feed on saline plants.

The details of the process which is used have not been very long known. One of the first writers who gave a description of this operation is father Sicard. He informed us, in 1716, that distilling vessels were charged with the foot of the excrements of oxen, to which sea salt and camels urine were added.

Mr. Lemaire, consul at Cairo, in a letter written to the Academy of Sciences in 1720, affirms that neither urine nor sea salt are added.

Mr. Hasselquist has communicated to the Academy of Stockholm a considerably extensive description of the process: by which we learn that the dung of all animals which feed on saline plants is indiscriminately used, and that the foot is distilled, to obtain sal ammoniac.

This dung is dried by applying it against the walls: and it is burned instead of wood, in such countries as do not possess that fuel. The sublimation is performed in large round bottles of one foot and a half diameter, terminating in a neck of two inches in height; and they are filled to within four inches of the neck. The fire is kept up during three times twenty-four hours; the salt is sublimed to the upper part of these vessels, where it forms a mass of the same figure as the vessels themselves. Twenty pounds of foot afford six pounds of sal ammoniac, according to Rudenskiöld.

I was always of opinion that sal ammoniac might be extracted by treating the dung of the numerous animals which feed on saline plants in the plains of La Camargue and La Crau, in the same manner; and after having procured, with the greatest difficulty, two pounds of the foot, I extracted from it four ounces of sal ammoniac. I must observe, to save much trouble to those who may wish to follow this branch of commerce, that the dung produced during the summer, the spring, or the autumn, does not afford this salt. I did not know to what circumstance to attribute the versatility of my results, until I found that these animals do not eat saline vegetables, excepting at the time when fresh plants cannot be had; and that they are reduced to the necessity of having recourse to saline plants only during the three winter months. This observation appears to me to be a proof, that marine salt is decomposed in the first passages; and that the soda is modified to the state of ammoniac.

Sal ammoniac is continually sublimed through the apertures of volcanic mountains. Mr Feber found it; and Mr. Sage admitted its existence among volcanic products.

It is found in the grottos of Puzzolo, according to Messrs. Swab, Scheffer, &c.

It is found in the country of the Calmucs. Model analysed it.

It is also produced in the human body, and exhales by perspiration in malignant fevers. Mr. Model has proved this fact in his own person: for at the time of a violent sweat which terminated a malignant fever, he washed his hands in a solution of pot-ash, and observed that a prodigious quantity of alkaline gas was disengaged.

Sal ammoniac crystallizes by evaporation in quadrangular pyramids. It is often obtained in rhombic crystals by sublimation. The concave face of the loaves of sal ammoniac in commerce is sometimes covered with these crystals.

This salt has a penetrating, acrid, urinous taste. It possesses a degree of ductility which renders it flexible, and causes it to yield to a blow of the hammer. It does not change in the air; which circumstance renders it probable that our sal ammoniac is different from that mentioned by Pliny and Agricola, as that attracted humidity. Three parts and a half of water dissolve one part of sal ammoniac, at sixty degrees of Fahrenheit's thermometer: a considerable degree of cold is produced by its solution.

One hundred parts of sal ammoniac contain fifty-two parts acid, forty ammoniac, and eight water.

This salt is not at all decomposed by clay; nor by magnesia except with difficulty, and in part only; but it is completely decomposed by lime and fixed alkalis. The sulphuric and nitric acids disengage its acid.

This salt is used in dyeing, to bring out certain colours. It is mixed with aqua fortis, to increase its solvent power.

It is used in soldering; in which operation it possesses the double advantage of clearing the metallic surface, and preventing its oxidation.

## CHAPTER V.

*Concerning the Nitro-muriatic Acid.*

THE acid which we call Nitro-muriatic, is a combination of the nitric and muriatic acids.

Our predecessors distinguished it by the name of Aqua Regia, on account of its property of dissolving gold.

There are several known processes for making this mixed acid.

If two ounces of common salt be distilled with four of nitric acid, the acid which comes over into the receiver will be good nitro-muriatic acid.

This is the process of Mr. Baumé.

The nitrate of pot-ash may be decomposed by distilling two parts of muriatic acid from one of this salt: good aqua regia is the product of this operation; and the residue is a muriate of pot-ash, according to Mr. Cornette.

Boerhaave affirms that he obtained a good aqua regia, by distilling a mixture of two parts of nitre, three of sulphate of iron or martial vitriol, and five of common salt.

The simple distillation of nitre of the first boiling affords aqua regia; which is employed by the dyers in the solution of tin, for the composition of the scarlet dye. This aqua fortis is a true aqua regia: and it is by virtue of the mixture of acids that it dissolves tin; for if it consisted of the nitric acid in a state of too great purity, it would corrode and oxide the metal without dissolving it. The dyers then say that the aqua fortis precipitates the tin; and they correct the acid by dissolving sal ammoniac or common salt in it.

Four ounces of sal ammoniac in powder, dissolved gradually, and in the cold, in one pound of nitric, form an excellent aqua regia. An oxygenated muriatic acid gas is disengaged for a long time; which it is imprudent to attempt to coerce, and which ought to be suffered to escape by convenient apertures.



Aqua regia is likewise formed by mixing together two parts of pure nitric acid and one of muriatic acid.

The very evident smell of oxygenated muriatic acid, which is disengaged in every process which can be adopted to form the acid at present in question ; and the property which it possesses, equally with the oxygenated muriatic acid, of dissolving gold, have led certain chemists to infer that, in the mixture of these two acids, the muriatic acid seized the oxygen of the nitric, and assumed the character of oxygenated muriatic acid : so that the nitric acid was considered as answering no other purpose than that of oxygenating the muriatic. But this system is inconsistent ; and though the virtues of the muriatic acid are modified by this mixture, and it is oxidized by the decomposition of a portion of the nitric acid, nevertheless the two acids still exist in the aqua regia : and I am convinced that the best made aqua regia, saturated with pot-ash, will afford the ordinary muriate, the oxygenated muriate, and the nitrate. It appears to me that the powerful action of aqua regia, depends simply on the union of the two acids ; one of which is exceedingly well calculated to oxidize the metals, and the other dissolves the oxides or calces with the greatest avidity.

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## CHAPTER VI.

### *Concerning the Acid of Borax.*

THE acid of borax, more generally known by the name of Homberg's Sedative Salt, is almost always afforded by the decomposition of the borate of soda, or borax. But it has been found perfectly formed in certain places ; and we have reason to hope that we shall speedily acquire more accurate information respecting its nature.

Mr. Hocfer, director of the Pharmacies of Tuscany, was the first who detected this acid salt in the waters of the lake Cherchiajo, near Monte-rotondo, in the inferior province of Sienna: these waters are very hot, and they afforded him three ounces of the pure acid in one hundred and twenty pounds of the water. This same chemist having evaporated twelve thousand two hundred and eighty grains of the water of the lake of Castelnovo, obtained one hundred and twenty grains. He presumes, moreover, that it might be found in the water of several others lakes, such as those of Lasso, Monte-cerbeloni, &c.

Mr. Sage has deposited in the hands of the Royal Academy of Sciences some acid of borax. brought from the mines of Tuscany by Mr. Besson, who collected it himself.

Mr. Westrumb found sedative salt in the stone called Cubic Quartz of Lunenburg. He obtained it by decomposing this stone by the acids of sulphur, nitre, &c. The result of his analysis is the following:

Sedative salt	—	$\frac{6}{10}$
Calcareous earth	—	$\frac{1}{10}$
Magnesia	—	$\frac{1}{10}$
Clay and filex	—	$\frac{2}{100}$
Iron	—	$\frac{1}{100}$ to $\frac{2}{100}$

This stone according to the observations of Laffius, has the form of small cubical crystals, sometimes transparent, in other specimens milky, and affords sparks with the steel.

The acid of borax is generally found combined with soda. It is from this combination that it is disengaged, and obtained either by sublimation or crystallization.

When it is proposed to obtain it by sublimation three pounds of calcined sulphate of iron, and two ounces of borate of soda are dissolved in three pounds of water. The solution is then filtered, and evaporated to a pellicle; after which the sublimation is performed in a cucurbit of glass with its head. The acid of borax attaches itself to the internal surface of the head, from which it may be swept by a feather.

Homborg obtained it by decomposing of borax with the sulphuric acid. This process succeeded with me wonderfully well. For this purpose I make use of a glass cucurbit with its head, which I place on a sand bath. I then pour upon the borax half its weight of sulphuric acid, and proceed to sublimation. The sublimed acid is of the most beautiful whiteness.

Stahl, and Lemery the younger, obtained the same acid by making use of the nitric and muriatic acids.

To extract the acid of borax by crystallization, the borax is dissolved in hot water, and an excess of sulphuric acid is poured in. A salt is deposited during the cooling on the side of the vessel, in the form of thin round plates, applied one upon the other. This salt when dry, is very white, very light, and of a silvery appearance. It is the acid of borax.

We are indebted to Geoffroy for this process. Baron has added two facts: the first, that the vegetable acids are equally capable of decomposing borax; and the second, that borax may be regenerated by combining the acid of borax with soda.

This acid may be purified by solution, filtration, and evaporation; but it must be observed, that a considerable part is volatilized with the water which flies off in the evaporation.

The acid of borax has a saline cool taste. It colours the tincture of turnsole, syrup of violets, &c. red.

One pound of boiling water dissolved no more than one hundred and eighty-three grains, according to Mr. De Morveau.

Alcohol dissolves it more easily; and the flame which this solution affords is of a beautiful green. This acid, when exposed to the fire, is reduced to a vitriform and transparent substance, instead of rising; which proves, as Rouelle has observed, that it is only sublimed by favour of the water, with which it forms a very volatile compound.

As most of the known acids decompose this acid, and exhibit it in the same form, it has been thought a justifiable conclusion that it exists ready formed in the

borax. Mr. Baumé has even affirmed that he composed this acid by leavning a mixture of grey clay, grease, and cows dung exposed to the air in a cellar. But Mr. Wiegleb, after an unsuccessful labour of three years and a half, thinks himself authorized to give a formal negative to the French chemist.

Mr. Cadet has endeavoured to prove——1. That the acid of borax always retains a portion of the acid employed in the operation. 2. That this same acid has still the mineral alkali for its basis.—Mr. De Morveau has, with his usual sagacity, discussed all the proofs brought forward by Mr. Cadet; he has shewn that none of them are conclusive, and that the acid of borax is entitled to retain its place among the chemical elements.

## ARTICLE I.

### *Borate of Pot-ash.*

The acid of borax combined with pot-ash forms this salt. It may be obtained either by the direct combination of these two separate principles, or by decomposing borax by the addition of pot-ash.

This salt, which is yet little known, afforded Mr. Baumé small crystals.

The acids disengage it by seizing its alkaline base.

## ARTICLE II.

### *Borate of Soda.*

This combination forms Borax, properly so called.

It is brought to us from the Indies; and its origin is still unknown\*.

The article Borax may be consulted in Bomare's Dictionary of Natural History.

\* The origin of borax is very well ascertained in two Papers, in the seventy-seventh volume of the Philosophical Transactions, Numbers xxviii and xxix. It is dug up in a crystallized state from the bottom of certain salt lakes in a mountainous, barren, volcanic district, about twenty-five days journey to the eastward of Lassa, the capital of the kingdom of Thibet. T.



It does not appear that borax was known to the ancients. The chrysocolle, of which Dioscorides speaks, was nothing but an artificial solder composed, by the goldsmiths themselves, with the urine of children and rust of copper, which were beaten together in a mortar of the same metal.

The word Borax is found for the first time in the works of Geber. Every thing which has been written since that time concerning borax, is applicable to the substance which is at present known to us by that name.

Borax is found in commerce in three different states.—

The first is brute borax, tincall, or chrysocolle. It comes to us from Persia, and is enveloped and soiled by a greasy covering. The pieces of brute borax have almost all of them the form of a six-sided prism, slightly flattened, and terminated by a dihedral pyramid. The fracture of these crystals is brilliant, with a greenish cast. This kind of borax is very impure. It is pretended that borax is extracted from the Lake of Necbal, in the kingdom of Grand Thibet. This lake is filled with water during the winter, which exhales in the summer; and when the waters are low workmen enter, who detach the crystals from the muddy bottom, and put them into baskets.

The West Indies contain borax. It is to Mr. Antony Carera, a physician established at Potosi, that we are indebted for this discovery. The mines of Riquintipa, and those in the neighbourhood of Escapa, afford this salt in abundance. The natives use it in the fusion of copper ores.

The second kind of borax known in commerce comes from China. It is purer than the preceding, and has the form of small plates crystallized upon one of their surfaces, on which the rudiments of prisms may be perceived. This borax is mixed with a white powder, which appears to be of an argillaceous nature.

These several kinds of borax have been purified at Venice for a long time, and afterwards in Holland; but Messrs. Laguiller refine it at present in Paris: and this

purified borax forms the third kind which is met with in commerce.

In order to purify borax, nothing more is necessary than to clear it of the unctuous substance which soils it, and impedes its solution.

Crude borax added to a solution of mineral alkali, is more completely dissolved, and may be obtained of considerable beauty by a first crystallization; but it retains the alkali made use of: and borax, purified in this manner, possesses a greater portion of alkali than in its crude state.

The oily part of borax may be destroyed by calcination. By this treatment it becomes more soluble, and may in fact be purified in this way. But the method is attended with a considerable loss, and is not so advantageous as might be imagined.

The most simple method of purifying borax, consists in boiling it strongly, and for a long time. This solution being filtrated, affords by evaporation crystals rather foul, which may be purified by a second operation similar to the foregoing. I have tried all these processes in the large way; and the latter appeared to me to be the most simple.

Purified borax is white, transparent, and has a somewhat greasy appearance in its fracture.

It crystallizes in hexahedral prisms, terminated by trihedral and sometimes hexahedral pyramids.

It has a styptic taste.

It converts syrup of violets to a green.

When borax is exposed to the fire, it swells up, the water of crystallization is dissipated in the form of vapour; and the salt then becomes converted into a porous, light, white, and opaque mass, commonly called *Calcined Borax*. If the fire be more strongly urged, it assumes a pasty appearance, and is at length fused into a transparent glass of a greenish yellow colour, soluble in water; and which loses its transparency by exposure to the air, in consequence of a white efflorescence that forms upon its surface.

This salt requires eighteen times its weight of water, at the temperature of sixty degrees of Fahrenheit's thermo-

meter, to dissolve it. Boiling water dissolves one-sixth of its weight.

Barytes and magnesia decompose borax. Lime-water precipitates the solution of this salt; and if quick-lime be boiled with borax, a salt of sparing solubility is formed, which is the borate of lime.

Borax is used as an excellent flux in docimastic operations. It enters into the composition of reducing fluxes, and is of the greatest use in analyses by the blow-pipe. It may be applied with advantage in glass manufactories; for when the fusion turns out bad, a small quantity of borax re-establishes it. It is more especially used in soldering. It assists the fusion of the solder, causes it to flow, and keeps the surface of the metals in a soft or clean state, which facilitates the operation. It is scarcely of any use in medicine. Sedative salt alone is used by some physicians; and its name sufficiently indicates its application.

Borax has the inconvenience of swelling up, and requires the greatest attention on the part of the artist who uses it in delicate works, more especially when designs are formed with gold of different colours. It has been long a desideratum to substitute some composition in the room of borax, which might possess its advantages without its defects.

Mr. Georgi has published the following process:—"Natron, mixed with marine salt and Glauber's salt, is to be dissolved in lime-water; and the crystals which separate by the cooling of the fluid may be set apart. The lixivium of natron is then to be evaporated; and this salt afterwards dissolved in milk. The evaporation affords scarcely one-eighth of the natron employed, and the residue may be applied to the same uses as borax."

Messrs. Struve and Exchaquet have proved that the phosphate of pot-ash, fused with a certain quantity of sulphate of lime, forms an excellent glass for soldering metals, —See the *Journal de Physique*, t. xxix. p. 78, 79.

## ARTICLE III.

## Borate of Ammoniac.

This salt is still little known. We are indebted to Mr. De Fourcroy for the following indications :—He dissolved the acid of borax in ammoniac, and obtained by evaporation a bed or plate of crystals connected together, whose surface exhibited polyhedral pyramids. This salt has a penetrating and urinous taste ; it renders the syrup of violets green ; gradually loses its crystalline form, and becomes of a brown colour, by the contact of air. It appears to be of considerable solubility in water. Lime disengages the volatile alkali.



## PART THE SECOND.

### CONCERNING LITHOLOGY; OR AN ACCOUNT OF STONY SUBSTANCES.

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#### INTRODUCTION.

**T**HE object of Lithology consists in the study of stones and earths.

It is generally agreed to call those substances by the name of Earth or Stone, which are dry, brittle, inodorous, insipid, scarcely or not at all soluble in water, and of a specific gravity not exceeding 4,5.

There is no one who has seriously attended to the study of lithology, without being at the same time aware of the necessity of establishing divisions to facilitate the knowledge of stones, and to remove the numberless difficulties which would otherwise oppose the acquisition of that knowledge.

It is an obvious difference between living creatures and the subjects of the mineral kingdom, that these last are continually modified by external causes, such as air, water, fire, &c. while the former, being animated and governed by an internal force, possess characters of a more definite and unchangeable nature. The forms of these depend upon their organization; and, in general, the proceedings of nature respecting them are more constant, and better ascertained.

The earthy element appears to be passive of itself; it is obedient only to the laws of inanimate bodies; and we may refer all the phenomena of formation or decomposition, which a stone is susceptible of, to the mere law of affinities.

This, no doubt, is the cause of that variety of forms, and that mixture of principles, which scarcely permit the naturalist to establish his system upon fixed bases, or to found it upon constant and invariable characters.

If we take a view of the proceedings of all the naturalists who have hitherto written, we may easily reduce them to three classes.

1. The first class, carried by the imagination alone to that epocha when this globe issued from the hands of the Creator, have followed the actions of the various destructive agents which alter or overturn its surface. In this way they have shewn us the various rocks successively deposited or placed upon the primitive globe; and, by surveying the great phenomena which have happened upon our planet, they have acquired ideas more or less accurate respecting the vast works of decomposition and formation.

2. Others have busied themselves in enquiring, by analysis, what are the earths or primitive matters out of which all the stones we are acquainted with are composed. This class of philosophers have supplied us with the most valuable acquisitions respecting the nature, the uses, and the decompositions of these substances: but the results of analysis, though necessary in acquiring accurate notions of each stone, are not of themselves sufficient to form the basis of a method of classing; because these characters are too difficult to be acquired, and at most can be used only as supplementary in the establishment of such other methods as may be employed.

3. Almost all the systems of classification hitherto adopted, are founded upon the external characters of earthy substances.

Some naturalists have sought, in the variety of forms exhibited by the productions of the mineral kingdom, such principles of division as to them appeared sufficient. But not to mention that the same form frequently obtains in very different stones, this character is rarely found, and we are ignorant of the crystallization of most of the known earths: the crystallization cannot therefore be considered but as an accessory or secondary circumstance.

Other naturalists have established their divisions upon certain properties easy to be ascertained, such as that of effervescing with acids, giving fire with the steel, &c. But these characters do not appear to be sufficiently strict, nor sufficiently exclusive; for nothing is more common than to find a mixture of the fragments of primitive rocks with those of calcareous stones. Our province exhibits examples of this every step we take; and these mixtures, hardened by time, possess both the fore-mentioned characters. There are also stones which, without changing their nature, give fire with the steel, or effervesce with acids, accordingly as they are more or less divided. Such is the lapis lazuli, which effervesces when pulverized, but strikes fire when in the mass; the slate likewise effervesces when in powder, but not in the mass. The classification, therefore, which is founded on these characters, is not rigorous, and may at the most be made use of in conjunction with others.

M. D'Aubenton is the naturalist who appears to me to have distributed mineral substances with the greatest order of any who has hitherto undertaken that task; every thing which he says on this subject shews the experienced eye of the observer; and he has drawn from the external characters of bodies all the characters possible to be had from that source. But he could not avoid the defects which necessarily accompany the principles on which he has founded his system.

Deeply impressed with a sense of the insufficiency of these methods, as well as of the slight opportunities I have possessed of improving them, my endeavours have been exerted in collecting together all the characters which are capable of affording any useful indications. In this pursuit, I have joined the characters of the naturalist to those of the chemist; and though the method which I have adopted be very far from that degree of perfection which might be desired, I nevertheless present it to the public with confidence. It differs but little from that followed by Messrs. Bergmann and Kirwan; a circumstance which at least affords a prejudice in its favour. The peculiar advantages which, in my opinion, it appears

to possess, are—1. The lithologic productions are distributed equally, and into three classes. 2. All the analogous productions are brought together, and arranged as it were in a natural order. In a word, this system has fixed my own ideas in the most precise manner; and this has more particularly induced me to propose it to the public\*.

The various earths beneath our feet are, in general, combinations; and chemists, by decomposing these substances, have succeeded in obtaining, in the last analysis, principles which may be considered as earthy elements, until subsequent acquisitions shall either confirm or destroy our ideas on this subject.

The earthy elements most extensively distributed are five in number; namely, Lime, Magnesia, Barytes, Alumine, and Silix.

\* I consider what is here published respecting Lithology as a simple and short sketch of the principles which I explain in my Lectures. It would be judging me with too much severity, if the reader were to suppose that my present design is to exhibit a complete performance.

A more intimate acquaintance with this subject may be obtained by the perusal of the following works:

1. *Essai d'un Art de Fusion, à l'Aide de l'Air Vital*, par Erhmann. *Mémoires de M. Lavoisier sur le même sujet.*—*Mémoires de M. D'Arcet, sur l'Action d'un Feu égal, violent, et continu, sur un grand nombre de Terres, Pierres, &c.*

2. The works of Margraff and Pott, more especially the *Lithogognesia* of the latter.

3. *Les Pesanteurs Spécifiques des Corps*, par M. Brissot.

4. *Elements of Mineralogy*, by Mr. Kirwan.

5. *Le Manuel du Minéralogiste de Bergmann*, enrichi de Notes par M. l'abbé Mongez.

6. *La Minéralogie* de M. Sage.

7. *Les Ouvrages sur la Cryсталlographie* de M. de Romé de Lisse, de M. l'abbé Haüy, &c.

8. *Le Tableau Méthodique des Minéraux*, par M. D'Aubenton.

9. *La Minéralogie* de M. le Comte de Buffon; in which that celebrated writer has collected a great number of valuable facts, whose merit is independent of all theory.

10. *The Mineralogical Works of Messrs. Jars, Dietrich, de Born, Ferber, Trebra, Pallas, Cmelin, Linné, Dolomieu de Saussure de la Peyrouse, &c.*

11. *The excellent Analyses of Stones*, published from time to time by Pott, Margraff, Bayen, Bergmann, Gerard, Scheele, Achard, Mongez, &c.



We shall not treat of the other primitive earths announced by Mr. Klaproth, in the adamantine spar, and in the jargon of Ceylon, because they are yet too slightly known and too scarce, to have any influence upon our present division.

Nature appears to have formed all the mixtures and combinations which constitute stones, out of the primitive earths here spoken of.

If we direct our attention to the nature of these mixtures and combinations, we shall distinguish three habits, or modes, which establish three grand divisions. We shall immediately perceive that these earths are, in some instances, combined with acids, which form saline stones; that in other instances they are mixed with each other, and form stones properly so called; and that in other instances, again, these stones, so formed by the mixture of primitive earths, are united together, or fixed in a gluten or cement, which forms rocks, pebbles, or compound stones.

We shall therefore distinguish three classes in Lithology: the first will comprehend saline stones; the second stones, properly so called, or earthy mixtures; and the third rocks, or stony admixtures.

We consider it as indispensably necessary to explain the nature of the primitive earths, before we can proceed to treat of their combinations.

#### I. Lime.

This earth has been found totally disengaged from all combination, near Bath.—See Falconer on the Bath Waters, vol. i. p. 156 and 157. But as this is perhaps the only observation of the kind which we possess, it is indispensably necessary to shew the process by which lime may be obtained in a state of the greatest purity.

For this purpose chalk is to be washed in boiling distilled water, then dissolved in distilled acetous acid, and precipitated by the carbonate of ammoniac, or mild volatile alkali. The precipitate, being washed and calcined, is pure lime.

This earth possesses the following characters:

1. It is soluble in six hundred and eighty times its weight of water, at the temperature of sixty degrees of Fahrenheit. Kirwan.

2. It has a penetrating, acrid, and burning taste.

3. Its specific gravity is about 2,3 according to Kirwan, and 2,720 according to Bergmann.

4. It seizes water with great avidity; at the same time that it falls into powder, increases in bulk, and emits heat.

5. Acids dissolve it without effervescence, but with the production of heat.

6. The borate of soda, or borax, the oxides of lead, and the phosphates of urine, dissolve it by the blow-pipe without effervescence.

It appears to be infusible alone, as it has resisted the heat of flame urged by a stream of vital air.—See the Memoir of Mr. Lavoisier.

When it is mixed with acids, it forms a fusible combination; and it hastens the fusion of aluminous, siliceous, and magnesian earths, according to the experiments of Messrs. Darcet and Bergmann.

## II. Barytes, or Ponderous Earth.

We are indebted to the celebrated chemists Gahn, Scheele, and Bergmann for our knowledge of this earth.

It has not yet been found exempted from all combination; but in order to obtain it in a suitable degree of purity, the following process may be used:

The sulphate of barytes, or ponderous spar, which is the most usual combination met with on the earth, is to be pulverized, and calcined in a crucible, with an eighth part of powder of charcoal: the crucible must be kept ignited during an hour; after which the calcined matter is to be thrown into water: it communicates a yellow colour to this fluid, at the same time that a strong smell of hepatic gas is emitted; the water is then to be filtered, and muriatic acid poured in: a considerable precipitate falls down, which must be separated from the fluid by filtration. The water which passes through the filter holds the muriate of barytes, or marine salt of ponderous earth, in solution. The carbonate of pot-ash, or

mild vegetable alkali, in solution, being then added, the ponderous earth falls down, in combination with the carbonic acid; and this last principle may be driven off by calcination.

1. Pure barytes is of a pulverulent form, and extremely white.

2. It is soluble in about nine hundred times its weight of distilled water, at the temperature of sixty degrees, according to Kirwan.

3. The Prussiate of pot-ash, or Prussian alkali, precipitates it from its combination with the nitric and muriatic acids. This habitude distinguishes it from other earths.—See Kirwan.

4. It precipitates alkalis from their combinations with acids.

5. Barytes exposed, by Mr. Lavoisier, to flame fed with oxygenous gas, was fused in a few seconds: it extended itself upon the surface of the coal; after which it began to burn and detonate until the whole was nearly dissipated. This kind of inflammation is a character common to metallic substances; but when the barytes is pure it is perfectly infusible.—See Lavoisier.

Ponderous earth urged by the blow-pipe makes little effervescence with soda, but is perceptibly diminished: it dissolves in the borate of soda with effervescence, and still more with the phosphates of urine.—See the abbé Mongez' *Manuel du Minéralogiste*.

6. Its specific gravity exceeds 4,000, according to Kirwan.

### III. Magnesia, or Magnesian Earth.

This earth has been no where found disengaged from all foreign substances; but in order to obtain it in the utmost possible state of purity, the crystals of the sulphate of magnesia, or Epsom salt, are to be dissolved in distilled water, and decomposed by the carbonate of alkali. The precipitate must then be calcined, to disengage the carbonic acid.

1. Pure magnesia is very white, very friable, and, as it were, spongy.

2. Its specific gravity is about 2,33, according to Kirwan.
3. It is not perceptibly soluble in water when pure; but when it is combined with the carbonic acid, it is soluble; and cold water has a stronger action on it than hot, according to the experiments of Mr. Butini.
4. It has no perceptible action on the tongue.
5. It slightly converts the tincture of turnsole to a green.
6. Mr. Darcet has observed, that a strong heat agglutinates it more or less; but Messrs. De Morveau, Butini, and Kirwan, found that it was not fusible; and the experiments of Mr. Lavoisier have proved that it is as infusible as barytes and lime.

The borate of soda, and the phosphates of urine, dissolve it with effervescence.—See the abbé Mongez.

#### IV. *Alumine, or Pure Clay.*

This earth is not more exempt from mixture and combination than the foregoing; and in order to obtain it in a state of purity, the sulphate of alumine is dissolved in water, and decomposed by effervescent alkalis.

1. Pure clay seizes water with avidity, and may then be kneaded. It adheres strongly to the tongue.

2. Its specific gravity does not exceed 2,000, according to Kirwan.

3. When exposed to heat, it dries, contracts, shrinks, and becomes full of clefts. A considerable degree of heat renders it so hard that it gives fire with the steel.

When it has been well baked, it is no longer capable of uniting with water; but requires to be dissolved in an acid, and precipitated, in order that it may resume this property.

The experiments of Mr. Lavoisier shew that pure alumine is capable of an imperfect fusion, approaching to the consistence of paste, by heat excited by a current of vital air. It is then transformed into a kind of very hard stone, which cuts glass like the precious stones, and which very difficultly yields to the file.

The mixture of chalk singularly assists the fusion of this earth: it is fusible in a crucible of chalk, according to Mr. Gerhard, but not in a crucible of clay.



The borate of soda, and the phosphates of lime, dissolve it.—See Kirwan and the abbé Mongez.

According to the experiments of Mr. Dorthes, the purest native clays, and even that which is precipitated from alum, contain a small quantity of iron in the state of oxide; and it is from this principle that the earthy smell which is emitted by moistened clays, arises: it is very difficult to deprive them of it.

V. *Silex, or Quartzose Earth, Vitrifable Earth, &c.*

This earth exists nearly in a state of purity in rock crystal. But when it is required to be had in a state of purity free from all suspicion, one part of fine rock crystal may be fused with four of pure alkali. The fused mass must then be dissolved in water, and precipitated by an excess of acid.

1. Pure silex possesses a singular degree of roughness and asperity to the touch. It is absolutely void of all disposition to adhere; and its particles, when agitated in water, fall down with extreme facility.

2. Its specific gravity is 2,65.

3. Bergman had affirmed that water might dissolve it; and Mr. Kirwan has pretended that 10,000 parts of water might hold one of silex in solution, at the ordinary temperature of the atmosphere; and might even take up a greater quantity at a higher temperature.

The fluoric acid dissolves it; and lets it fall when it comes in contact with water, or when it is considerably cooled.

5. Alkalis dissolve it in the dry way, and form glass; but they attack it likewise in humid way, and are capable of dissolving one-sixth part of their weight when it is in a state of extreme division.

6. The burning mirror does not fuse it; but a current of vital air produced a commencement of fusion on its surface.—See Lavoisier.

Before the blow-pipe soda dissolves it with effervescence. The borate of soda dissolves it slowly, and without ebullition.

CLASS I.

Concerning the Combination of Earths with Acids.

This class, which comprehends the combination of primitive earths with acids, naturally exhibits five genera.

GENUS I.

Earthy Salts with Basis of Lime.

The combination of lime with various acids affords the several species of calcareous salts comprehended in this genus.

SPECIES I.

Carbonate of Lime, or Calcareous Stone.

The combination of lime with the carbonic acid is very commonly met with, and comprehends all the stones which have hitherto been distinguished under the names of lime-stone, calcareous stone, &c.

The characters of the carbonates of lime are—1. They effervesce with certain acids. 2. They are converted into lime by calcination.

The formation of these stones appears to us to be, for the most part, owing to the wearing down of shells. The identity of the constituent principles of shells and calcareous stones, and the presence of these same shells, more or less altered, in the lime stone mountains, authorize us to conclude that a great part at least of the calcareous mass of our globe owes its origin to this cause only.

Though our imagination appears to assent with difficulty in referring effects of so wonderfully extensive a nature to a cause apparently so weak, we are compelled to admit it when we take a flight view of the known history of shells.

In fact, we observe the numerous class of shell animals which possess this stony covering almost at the instant of their origin. We see it insensibly become thick and enlarged by the apposition of new coverings; and this

shell at length comes to occupy a volume fifty or sixty times larger than that of the animal which produced it. Let us consider the prodigious number of animals which emit this stony transudation; let us attend to their speedy augmentation, their multiplication, and the short period of their life, the mean term of which is about ten years, according to the calculation of the celebrated Buffon; let us multiply the number of these animals by the mass of shell they leave behind them—and we shall then arrive at the mass which the shells of one single generation ought to form upon this globe. If we proceed further to consider how many generations are extinct, and how many species are lost, we shall be no longer surprised to find that a considerable part of the surface of the globe is covered with their remains.

It may easily be conceived that these shells, when carried along by currents of water, must strike together, and wear their respective surfaces; and that their pulverulent remains, after being long carried about and suspended by the waters, must at last subside, and form heaps or banks of shells, more or less altered according to circumstances.

But whatever may be admitted as the origin of this stone, it is found to exist in two principal states; that is to say, either in the form of crystals, or of irregular masses.

#### I. Crystallized Calcareous Stones.

A concurrence of circumstances which very seldom meet together, is required, in order that crystallization may take place. This is, doubtless, the reason why spars and calcareous crystals compose the smallest part of this genus. These crystals are found in the cavities of calcareous mountains; in the clefts which penetrate into the internal part of stones of this class; and generally in all places where waters find access, after having worn down calcareous stone to a state of extreme attenuation, nearly correspondent to solution.

Calcareous stone, in its crystallized state, presents us with several varieties of form; but the rhomboidal figure

appears to be the most constant and the most general. The environs of Alais abound with rhomboidal spars of the greatest beauty; they are transparent like those of Iceland, and double objects in the same manner.

It often happens that a group of rhomboidal crystals exhibits at its surface a number of pyramids more or less prominent, which consist of the angles of rhomboids of different degrees of length. It cannot but be admitted, with Mr. Romé de Lisle, that the pyramidal form is a slight modification of the rhomboid; for if a pyramid of spar be broken, it is reduced into elements of a rhomboidal figure.

The principal varieties of the pyramidal form are deduced more especially from the number of their sides; and when the pyramid is long and sharp, it is called dog-tooth spar, or hog-tooth spar.

Calcareous stones often affect the prismatic form; and this is likewise attended with some varieties.

The prism is frequently six-sided and truncated; sometimes it is terminated by a trihedral pyramid; and when the prism is very short, and its summit is almost entirely in contact with the ground, the crystal is known by the name of Lenticular Spar.

All the varieties of form which crystallized calcareous stones have hitherto presented, may be seen in the Crystallography of Mr. Romé de Lisle.

The specific gravity of calcareous spars is about 2.700 when pure, according to Kirwan.

They contain from thirty-four to thirty-six parts of carbonic acid, and from fifty-three to fifty-five of earth; the rest is water.—See Kirwan.

Spars often exhibit a smooth uniform surface, upon which the sulphuric acid takes but slight hold: they are sometimes contaminated with iron, which gives them various tinges.

## II. Calcareous Stones which are not crystallized.

Few calcareous stones affect any regular form: they lie almost always in strata, or immense blocks thrown or heaped together on the surface of the globe, in which we



cannot reasonably pretend to discern any primitive design of crystallization. The notion itself which we have of the formation of these mountains, and the stratified disposition of their parts, does not allow us to discern any other effect than the natural consequence of the flowing of water, which must have occasioned a contraction, and disposed the rocks in strata or beds.

It seems to me that two very natural divisions may be established among calcareous stones which are not crystallized: for they are either susceptible of a perfect polish, in which case they are called marbles and alabasters; or they are not susceptible of this polish, in which case they are called friable earths, tufa, &c.

*A. Calcareous stones susceptible of a perfect polish.*

Although it be proved from the experiments of chemists, and more especially from those of Mr. Bayen, that marbles contain a greater or less proportion of clay, we are under the necessity of placing them here; because the calcareous earth predominates to such a degree, that they cannot with propriety be placed elsewhere; and because they possess all the characters of lime-stone.

Marbles differ from other calcareous stones by the polish of which they are susceptible; and they are distinguished from each other by their colours.

White marble is usually the purest. We are acquainted with the marble of Carrara, and the ancient statuary marble of Paros.

Black marble is coloured either by a bitumen or by iron. Mr. Bayen found this metal in the proportion of five parts in the hundred. When it is veined by pyrites, it is called Portor.

There are an infinite number of varieties of coloured marble. The colouring part is in general owing to the alterations of the iron, which sometimes is obedient to the magnet, according to an observation of Mr. De Lisle. Blue and green marbles owe their colours to a mixture of schorle, according to Rinmann in his History of Iron.

The marble which presents the figure of shells appears to be formed simply out of a heap of shells connected by

a calcareous cement; it is known by the name of Luma-chello. That of Bleyberg in Carinthia forms one of the most beautiful species.

The marble which is called figured marble, exhibits either traces of vegetables, as that of Hesse; or ruins and rocks, like that of Florence. The dendrites appear to be formed merely by ferruginous infiltrations through the cracks of these stones.

Several naturalists have mentioned flexible marble. Father Jacquier described this in 1764, in the Gazette Littéraire; and the abbé De Sauvages has communicated to the Academy of Montpellier a description of the plates of flexible marble which are in the Palais Burgeois.

Alabasters are calcareous stones of the nature of marble: they appear to be formed like the stalactites, and are sometimes adorned with the most beautiful colours: these in general possess a certain transparency, with a stratiform texture variously coloured, and cause a double refraction of the light when they are sufficiently transparent. In the treatise of Mr. Brisson on the specific gravities of bodies, the reader will find the result of his valuable experiments on that of marbles, alabasters, and generally all the calcareous stones.

B. Calcareous stone not susceptible of a perfect polish.

Calcareous stones which are not susceptible of a perfect polish, are found either in masses, or in the pulverulent form; which circumstance will afford a foundation for our natural distinction.

1. Solid calcareous stone is in general the stone used for building; and this is found in several varieties, differing in fineness of grain, porosity, colour, consistence, or weight. These are gradations which establish the several qualities of stones; and are the cause why one hardens in the air, while another is decomposed. On these several accounts it is that the respective varieties are applied to various uses; and it is the business of the skilful artist who uses them to distinguish their qualities.

In the number of these stones used for building, there are some which imbibe and retain water, in consequence of which they are burst or crumbled by the frost; whereas

others suffer the water which they originally contained to escape, and become harder by the contact of the air.

2. Calcareous stone is sometimes found in the pulverulent form. Chalk is of this kind; and when it is white, and very finely divided, it is formed into those masses known in commerce by the name of Spanish White. For this purpose it is agitated in a vessel with water. The foreign substances, such as flints, pyrites, &c. are precipitated; the water is then decanted; and the chalk, which is held suspended, very soon subsides: this is dried, and divided into long square pieces, to form the Spanish White.

When a natural stream of water wears away this chalk, and afterwards deposits it, the result has been distinguished by the name of Gurrh; and when this possesses a certain consistence, arising from the mixture of argillaceous and magnesian earths, it is distinguished by the name of Agaric Mineral.

As calcareous earth is susceptible of extreme division, the water which wears it away, and is afterwards filtered through the clefts in rocks, deposits it gradually, and forms those incrustations known by the vulgar under the name of Petrifications, and by that of Stalactites among naturalists.

These calcareous depositions very frequently preserve the form of such substances as they have covered, and present figures of moss, roots, fruit, &c. which has given rise to an opinion that those substances were transformed into stone.

The increase of stalactites being accomplished by addition to their external surfaces, their texture exhibits concentric coats of different shades, accordingly as the water may have been charged with different colouring principles.

The cavities which are frequently found in calcareous mountains are often lined with stalactites; and these grottos form one of the most striking appearances which can present itself to the eyes of the naturalist.

The grandeur of these subterraneous places, the absence of light, the feeble glimmering of a torch, which only half enlightens the surrounding objects, render these

regions gloomy, majestic, and imposing. The multiplicity of figures, the variety of forms, and their resemblance to other objects, never fail to cause a high degree of astonishment in the mind of the mineralogical student. Among the infinite number of these forms, there are some which are very agreeable, such as the flos ferri, cauliflowers, lace, or fringes. Other very singular figures are likewise found, such as the priapolithes, pisolithes, oolithes, &c.

Mr. Lougeon of Ganges has observed, in the grotto called Des Demoiselles, a number of forms so varied and strange, as to exhibit a very astonishing collection.

These transudations, or rather these stony depositions, have given rise to a belief in the vegetation of stones. The celebrated Tournefort was of opinion that he had observed nature in the very fact, in the famous grotto of Antiparos, where he saw inscriptions engraved in the stone, but afterwards converted into reliefs. Baglivi has written a treatise on the vegetation of stones, in which he cites many facts of this nature.

All the world is acquainted with the depositions of the spring in the vicinity of Clermont; but the most surprising of all petrifying waters is that of Guancavelica in Peru. Barba, D. Ulloa, and Frezier, have given us a description of it. Feuille informs us that this water rises very hot in the middle of a square basin, and becomes petrified at a small distance from the spring. The water is of a yellowish white, and the incrustations have been used to build the houses of Guancavelica. The workmen fill moulds with its water, and some days afterwards they find them incrustated with this stone. The statuaries expose their moulds in this spring, and have only to give the polish in order to render their statues transparent. All the statues used in religious ceremonies, by the catholics of Lima, are of this substance, and are very beautiful.—*Journal des Observ.* tom. i. 434.

In the year 1760, Mr. Vegni devised a method of making a similar use of the very white chalk which is contained in the waters of the baths of St. Philip in Tuscany. For this purpose the water is suffered to run for the space



of near a mile, in order that it may deposit the sulphur, the selenite, and the tufa which it contains; and in this purified state it is used in the fabrication of bas reliefs. It is introduced at the roof of a building, into a closet constructed of planks fitted together. The water falls from twelve to fifteen feet in height, upon a wooden cross placed on a post; by which fall it is divided, and dashes laterally against sulphur moulds, which are placed on the sides of the cabinet. In this way it deposits the particles of the earth which it contained, and the mould becomes filled. Mr. Vigni placed the moulds upon pieces of wood which are moved circularly. This alabaster is as hard as marble; and the incrustation is more beautiful, and harder, in proportion as the position of the mould is more vertical, and its distance greater.

#### The Analysis and Uses of Calcareous Stone.

In 1755, Dr. Black proved that calcareous stone possesses, as one of its component parts, an air different from atmospheric air. He asserted that calcareous stone when deprived of this air by calcination, forms lime; and that lime might again pass to the state of calcareous stone by resuming the principle it had been deprived of. In 1764, Macbride supported this doctrine by new facts. Jacquin added other experiments to these; and proved that lime and alkalis owe their causticity to the subtraction of this fixed air, at the same time that he pointed out several methods of depriving them of it.

The processes which are most commonly used for the decomposition of lime-stone, are fire and acids; the first is used in the making of lime; the second in laboratories, when it is intended to procure the carbonic acid.

In order to form lime, the calcareous stone is calcined in furnaces, whose construction is varied according to the nature of the combustibles made use of.

When pit-coal is used, an inverted cone is constructed of vitrifiable stone, which is filled by alternate strata of coal and lime-stone; and the lime is taken out, after the operation, by an aperture at the top. In proportion as

the mass subsides, care is taken to supply the furnace at the top, in order that the flame and heat may not be lost.

Bergmann has observed that most specimens of calcareous stone which become black or brown by calcination, contain manganese, and that the lime which they produce is excellent.

According to Rinmann, the white calcareous stones which become black by calcination, contain about one tenth part of this substance.

Calcination deprives lime-stone of the acid and water which it contained. These two principles are evidently replaced by the matter of heat itself. The odour of fire which quick-lime emits; the light which it affords when slackend in a dark place; the colour which it communicates to the lapis causticus; the property which it possesses of producing the oxide and the glasses of lead—all prove to us, as Mr. Darcet observes in the *Journal de Physique* for 1783, that in proportion as the calcareous stone is deprived of the aëriform principle, it combines with the igneous principle, which cannot be displaced but by the way of affinities. The beautiful experiments of Meyer, when divested of all theory, prove the same thing.

It is proved, from the experiments of Dr. Higgins, that the best lime is that which is made with the hardest and most compact stone broken into small pieces, and heated slowly, until the furnace is become of a white heat. This heat must be kept up until the stone is no longer capable of effervescing with acids. The lime becomes over-burned if the ignition be carried to a greater degree; and the produce is then a frit, which is no longer capable of being divided in water, or of resuming with avidity the principles it had lost.

When pieces of calcareous stone of different sizes are calcined, the lime will not all be of equal goodness; the small pieces consisting of over-burned lime, while the larger pieces are scarcely altered in their central parts.

The best lime is that which is the most quickly divided by immersion in water, and affords the greatest quantity of heat in this process, which causes it to fall into the

finest powder. Good lime should likewise dissolve in the acetous acid without effervescence, and leave the least possible quantity of residue.

Lime continually endeavours to resume the acid and the water of which the stone was deprived by calcination : consequently, when it is left exposed to the air, it cracks, becomes heated, falls into powder with an increase of bulk, and resumes the property of effervescing. It is therefore of importance to use lime newly made, if the artist be desirous of possessing its whole force.

Lime is sparingly soluble in water, and this solution is called lime-water ; the lime may be precipitated by means of carbonic acid, which regenerates calcareous stone in the form of a precipitate.

Lime-water is used to indicate the presence, and determine the proportion, of carbonic acid in any mineral water.

Physicians prescribe it as an absorbent and detergent.

When lime-water is left in contact with the air of the atmosphere, a pellicle is formed at its surface, known by the name of the cream of lime ; this is the regenerated calcareous stone.

The superb basin of Lampi, one of the two principal reservoirs which furnish the Royal Canal of Languedoc with water, was found to leak at the junction of the stones. The skilful engineer who directs these works, Mr. Pin, caused lime to be slacked ; which, passing through these small apertures, because supplied with carbonic acid, and formed a crust, or very white covering, over its whole surface : so that all the stones of this fine piece of masonry are connected together by this cement ; and at present constitute one single undivided substance, impenetrable to water.

The regeneration of calcareous stone is very slowly effected by the processes hitherto described. But this may be expedited by presenting to the lime the principles with which it so strongly tends to combine : this is accordingly done in works in the large way.

Lime is usually slacked by pouring abundance of water upon it. A violent heat is thus excited ; the lime falls

down into powder, and a paste is afforded by strongly working the lime together in proportion as it becomes saturated.

The count Razoumoufski has taken advantage of the heat which is disengaged when lime is slacked, to combine the lime with sulphur.

The degree of heat proper to effect this combination is 70 of Reaumur. At this point the sulphur, which is placed in contact with the lime, liquefies, becomes of a red colour, and forms a true sulphure or hepar of lime.

Mortar is made simply by working sand, or other bodies insoluble in water, together with slacked lime.

We are acquainted with two kinds of sand at Montpellier; pit sand, and river sand: the former is almost always altered by a mixture of vegetable and calcareous earth, which weaken its efficacy; the second is purer, and better suited for the purpose. Instead of sand, the fragments or dust of stone may be used: the angles which these fragments present, and the roughness of their surface, contribute to give a consistence to the mortar.

The hardening of mortars appears to be owing merely to the progressive regeneration of lime-stone. They do not obtain the greatest degree of hardness of which they are susceptible, until they have resumed all the carbonic acid of which the stone was deprived: and this operation is very slow, unless the combustion be facilitated by well-known methods, which consist in mixing substances with the mortar which contain either the carbonic acid, or a principle analogous to it, such as vinegar.

It is this regeneration of lime-stone, which is effected by the lapse of time, that explains to us why the hardest stones afford the best lime; and why old mortars are found to possess a degree of hardness which modern artists have no hopes of attaining.

The remains of ancient buildings have induced certain philosophers to conclude, that the ancients were in possession of very valuable processes for the making of mortar. Mr. De la Faye was of opinion, that those enormous masses, in which the perfection of the mechanical processes of the ancients only was admired, were made by coffer



work ; and he imagined that he had discovered, in Vitruvius, Pliny, and Saint Augustin, that their process to extinguish lime differed from ours ; and that the great difference which appears to exist between the ancient and modern mortars depends more particularly upon this circumstance. These interesting researches have induced him to propose that the lime should be put into a basket, and suffered to slack in the air ; as he thinks by this means it would preserve a greater degree of force, and be less weakened than by the usual processes.

Loriot has attributed the superiority of the mortars of the ancients to the means which they used to dry them speedily ; and in consequence of these principles he mixes pounded bricks with flints, works the whole together with slacked lime, and dries the mass with one-fourth part of quick-lime. Care must be taken to use only lime which is finely pulverized and sifted ; for otherwise the mortar would crack, and be very imperfect.

Nature sometimes presents to us a suitable mixture of lime-stone and sand, to form an excellent mortar without any mixture of extraneous substances. Mr. De Morveau found this lime-stone in Burgundy ; Mr. De Puymaurin has described a species which he found in Berne ; and I have observed in Cevennes a natural mixture of this kind, in which the proportion of materials was so well assorted, that nothing more was necessary than to calcine it, and extinguish it in water, to form an excellent mortar.

#### SPECIES II.

Sulphate of Lime, Gypsum, Selenite, Plaster Stone.

The Plaster Stone loses its transparency by calcination ; at the same time that it becomes pulverulent, and acquires the property of again seizing the water of which it had been deprived, and resuming its hardness ; it does not give fire with the steel, nor effervesce with acids.

We are more particularly indebted to Margraff for our acquaintance with the constituent principles of plaster ; and from subsequent experiments the following proportion of the same principles has been assigned. One hundred parts of gypsum contain thirty sulphuric acid, thirty-two

pure earth, thirty-eight water; it loses nearly twenty per cent. by calcination.

We begin to be equally acquainted with the formation of this stone. The chevalier De Lamanon has asserted, that the numerous quarries of plaster which are found in the vicinity of Paris, are the deposition of an ancient fluviatile lake, formed by the Seine, Loise, and Marne, which flowed off on the side of Meulan. The wrought iron, and the various remains of animals which are found at the bottom of the quarries of Mont Matre, shew that its formation is not very ancient; and the indefatigable naturalist here cited considers the selenite as originally dispersed in the water, precipitated in consequence of its sparing solubility, and heaped together in places determined by currents, waves, and other circumstances.

These facts, highly interesting as they are in the natural history of plaster, are insufficient for the chemist who is desirous of knowing likewise in what manner, and under what circumstances, the combination of the sulphuric acid and lime is made. I shall proceed to communicate some observations which our province affords.

1. I have observed in a black and pyritaceous clay of Saint Sauveur, extracted out of the work called Perce-ment Dillon, many small needle-formed crystals of selenite, from four to eight lines in length. At the surface of the soil where the same clay is more decomposed, crystals of the same nature, but longer, thicker, and more numerous, are also found.

2. The marly and pyritous clay of Caunelle, near Mofson, abounds with beautiful crystals of rose-coloured plaster, in the form of cocks-combs, observed by Mr. Dorthes.

3. The plaster quarry of La Salle exhibits almost alternately strata of plaster and strata of black and pyritous clay, which effloresces in the air.

4. Near the bridge of Herepian, on the declivity of Castellet, at Gabian, and in many other places, I have constantly found crystals of gypsum mixed and confounded with pyritaceous clays.

5. The sulphureous depositions of solfatara often contain crystals of selenite.

From these facts it appears to me that the formation of gypsum may easily be conceived. It is not formed excepting in places where pyrites and clay more or less calcareous are found together: that is to say, its formation appears to be dependent on, and connected with, the presence of sulphur and lime.

Whenever, therefore, the pyrites is decomposed, the sulphuric acid which thence arises seizes the lime, and effloresces in small crystals, which are carried off by the water, and sooner or later deposited. I have observed perceptible depositions of plaster on the banks of rivulets which wash pyritous clays. I have likewise seen depositions of the same nature in rivers whose waters have been strongly concentrated by the burning heat of our summer. And consequently, if we suppose selenite to be dispersed in more considerable masses of water, there will be no difficulty in conceiving the formation of those strata which the plaster quarries exhibit.

Messrs. De Cazozy and Macquart have observed the transition of the gypsum of Cracovia to the state of calcedony. When the nucleus of calcedony is determined, it increases perceptibly in the course of time, even in cabinets; which proves that the quartzose juice, when once infiltrated into plaster, combines with the lime, and determines this transformation.

Mr. Dorthes has prove that the quartz, in cocks-combs at Passy, owed its origin to plaster; that this last substance having been carried away by solution, the quartzose juice has taken its place. Natural history exhibits several of these metamorphoses.

Gypsum is found in the earth in four different states.

1. In the pulverulent and friable form, which constitutes gypseous earth, fossil flour, &c.
2. In solid masses, which constitute plaster-stone.
3. In stalactites, or secondary depositions. In this place we may arrange the striated silky gypsums, the cauliflowerers, the gypseous alabasters, and that prodigious variety of forms which the stalactites assumes, whatever may be its component parts.
4. In determinate crystals, which usually exhibit the following forms.

1. The compressed tetrahedral rhomboidal prism.
2. The hexahedral prism truncated at its summit.
3. The decahedral rhomboid. I apprehend that the lenticular gypsum may be referred to this last form, as it appears to me to be composed of several rhomboids united together side-ways. At all events I have, as the last result, obtained the rhomboidal form, by decomposing this variety.

The colour of gypsum is subject to a great number of varieties, which are the signs of various qualities relative to its uses. The white is the most beautiful, but sometimes it is grey; and in this case is less esteemed, and less valuable.

The several states of the oxides of iron, with which it abounds in greater or less quantities, constitute its rose-coloured, red, black, &c. varieties.

The specific gravity of gypsum varies according to its purity.—See Messrs. Briffon and Kirwan: the latter found it sometimes of the weight of 2.32, and sometimes 1.87.

It is soluble in about five hundred times its weight of water, at the temperature of 60 degrees of Fahrenheit.

When it is exposed to heat, its water of crystallization is dissipated, it becomes opaque, loses its consistence, and falls into powder. If it be moistened, it becomes hard again, but does not resume its transparency; a circumstance which appears to prove that its first state is a state of crystallization.

If it be kept in a fire of considerable intensity, in contact with powder of charcoal, the acid is decomposed, and the residue is lime.

Its principles may likewise be separated by finely pulverizing it, and boiling it with alkali.

It is fusible by the blow-pipe according to Bergmann; and in a porcelain furnace, according to Darcet.

The management of the fire in the calcination of gypsum is of great consequence. Too much heat decomposes it; and too little does not enable it to unite, and form a hard substance with water.

Calcined gypsum divides and disperses itself in water, with which it forms a paste that may be cast into every



figure imaginable. We are indebted to this property for beautiful ornaments in the inside of our houses; but it cannot be used for external decorations because, its solubility in water renders it gradually destructible by that liquid.

## SPECIES III.

Fluate of Lime, Vitreous Spar, Fusible or Phosphoric Spar, Fluor Spar.

This stone is a combination of a peculiar acid, called the fluor acid, with lime.

It decrepitates on heated coals, like muriate of soda, or common salt. When slightly heated, it shines with a beautiful blue colour, that remains even under water, or in acids. The residue of this appearance of combustion is white and opake.

Its specific gravity is, in general, from 3.14 to 3.18, according to Kirwan.

This spar enters into fusion by a strong heat, and corrodes the crucible: it likewise fuses without effervescence with the mineral alkali, the borate of soda, and the phosphates of urine.

This stone possesses the most lively and various colours; and it is known under the names of false emerald, false emethyst, or false topaz, accordingly as its colour is green, violet, or yellow.

The blue fluor spars commonly owe their colour to iron, but sometimes to cobalt. Berlin Berchast, tom. ii. p. 330.—Green fluors are coloured by iron, according to Rinmann. The most usual form of fluuate of lime is the cubic, with all the modifications which accompany this primitive form.

When this stone is distilled with its own weight of sulphuric acid, the first product consists of elastic whitish vapours, which fill the receiver, and deposit a crust at the surface of the water, while the water itself becomes acidulous. The residue in the retort is sulphate of lime, according to Scheele. The crust which is formed on the water of the receiver is siliceous earth; and the water itself being saturated with the vapour, constitutes the fluoric acid.

The most astonishing property of this acid is doubtless that of seizing the siliceous earth, which is a constituent principle of the glass, and volatilizing it with itself.

In order to have the acid in a state of greater purity, and exempt from every mixture of *filex*, the operations are performed in retorts of lead; but Mr. De Puymaurin is convinced, as well as myself, that the acid even then is seldom pure, because the most beautiful fluor contains almost always a small quantity of *filex*, which the acid carries with it. The whitest, the most transparent, and the most regularly-crystallized fluor, distilled on the water bath in a leaden retort, afforded me an acid contaminated by a small quantity of *filex*.

Mr. Meyer having used every possible means to obtain this acid in a state of great purity, is convinced that when the acid does not find *filex* in the retort, it attacks the sides of the receiver, and becomes changed.

This acid may be preserved in bottles whose internal surfaces are coated with wax dissolved in oil.

The fluoric acid has some analogy with the muriatic; and some chemists have even confounded them together: but they differ essentially from each other.

The fluoric acid—1. When combined with pot-ash, presents a gelatinous substance, which when dry retains one-fifth of the alkali employed, and forms a true neutral salt. 2. It acts nearly in the same manner with soda. 3. With ammoniac it affords a jelly, which when dry exhibits all the appearances of *filex*. 4. When mixed with lime-water, it regenerates the fluuate of lime. 5. It does not attack gold, nor dissolve silver; and combines in preference with oxides, such as those of lead, iron, copper, tin, cobalt, and even of silver.

One part of the fluuate of lime, fused with four parts of caustic fixed alkali, forms a salt insoluble in water. The same quantity of fluuate of lime, treated in the same manner with the carbonate of pot-ash, or mild vegetable alkali, affords a soluble salt; and at the bottom of the water a calcareous earth is found, which proves that the fluoric acid is not separated but by double affinity.

This stone, which hitherto has not been employed but as a flux, or in the fabrication of ornaments, appears to

me to deserve the most particular attention. Its texture seems to be lamellated like the diamond; and like that stone it is capable of double refraction, as the abbé Ro-  
chon has observed. Its phosphorescence has likewise some relation with the combustibility of the diamond, and it has lively and varied colours. All these circumstances establish an analogy between these two substances; and might lead us to suspect that the constituent principles of the diamond exist in this stone, mixed and combined with an acid and lime, &c.

The fluoric acid possesses the very singular property of attacking glass, and dissolving and carrying off its siliceous part. Margraff first observed this property; but Messrs. De Puymaurin and Klaproth have very happily applied it to the art of engraving on glass.

This acid is employed to corrode the glass, in the same manner as aqua fortis is used to engrave upon copper.

Some authors, particularly Mr. Monnet, have endeavoured to prove that this acid was nothing else but a modification of the acid used in the decomposition of the spar. They seem to found their opinion chiefly on the circumstance, that the acid obtained exceeds in weight the spar made use of; but they have neglected the increase of weight which must arise from the erosion, dissolution, and mixture of the glass of the distilling vessels. And indeed these experiments do not appear to me to invalidate in the least the eternal truths which have issued from the laboratory of the celebrated Scheele; otherwise such modifications in the acids employed, would in my opinion afford a phenomenon still more astonishing than the existence of this peculiar acid.

#### SPECIES IV.

##### Nitrate of Lime, Calcareous Nitre.

This salt, as well as those which remain to be treated of in the present genus, exists only in waters. Their great solubility, and their spontaneous deliquescence, do not permit them to form durable masses, or to exist in the form of stones.

The nitrate of lime is principally formed near inhabited places; old plaster affords it in abundance by lixiviation. It is one of the salts which abound in the mother waters of the salt-petre makers; and it has been found in some mineral waters.

It is usually obtained in the form of small needles, applied sideways to each other.

When a solution of nitrate of lime is concentrated to a gelatinous consistence nearly equal to that of syrup, it forms, in process of time, crystals in hexahedral prisms.

Two parts of cold water dissolve one of this salt; and boiling water dissolves more than its own weight.

Its taste is bitter and disagreeable.

It liquifies easily on the fire, and becomes solid by cooling: if it be strongly calcined, and carried into the dark, it is luminous, and constitutes Baldwin's phosphorus.

It loses its acid in a violent and continued heat. When distilled in close vessels, it affords the same products as nitre by the decomposition of its acid.

Projected upon ignited coals, it detonates in proportion as it becomes dry.—See De Fourcroy.

Its acid may be disengaged by means of clay and of the sulphuric acid.

The alkalis and barytes precipitate its earth.

The sulphuric salts, and the carbonates of alkali, decompose it by double affinity.

#### SPECIES V.

##### Muriate of Lime, Calcareous Marine Salt.

This combination exists more especially in the waters of the sea; and contributes to give to these waters that bitter taste which has improperly been referred to bitumens that have no existence.

This salt is very deliquescent; one part and a half of water dissolves one of this salt; and hot water dissolves more than its own weight.

It may be made to crystallize by concentrating its solution to the 45th degree of Baumé, and exposing it afterwards in a cool place.



With these precautions it affords a salt in tetrahedral prisms terminated by four-sided pyramids.—See De Fourcroy.

It enters into fusion with a moderate heat; but is decomposed with great difficulty. It acquires by calcination the property of shining in the dark, and is called the phosphorus of Homberg.

It is decomposed by barytes and the alkalis. The concentrated sulphuric acid, poured upon a very strong solution of muriate of lime, disengages the acid in vapours, and forms a solid precipitate; an appearance which seems in an instant to transform two liquids into a solid, and produces a very striking effect. The theory of this phenomenon is easily deduced from the very great solubility of the muriate, and the almost absolute insolubility of the sulphate which takes its place.

#### SPECIES VI.

Phosphate of Lime, Calcareous Phosphoric Salt.

This phosphate of lime has been found in Spain, in the kingdom of Estramadura, by Mr. Bowle.

It is a whitish stone of considerable density, not hard enough to give fire with the steel. It is found in horizontal strata, reposing upon quartz, and exhibiting vertical, flattened, and close fibres. When thrown on ignited coals, it does not decrepitate, but burns quietly, and affords a beautiful green light, which seems to penetrate through it, and does not disappear so quickly but that a sufficient time is admitted to contemplate its brilliancy with admiration. Before the blow-pipe it runs into a white enamel, without boiling up; whereas bones support the most violent heat without fusion. Its habits with the nitric and sulphuric acids are the same as those of calcined bones; its acid may be separated and brought into the state of an animal glass; it may be decomposed, and the phosphorus extracted.

Mr. Proust, from whom we borrow these interesting details, observes likewise that this stone is found to compose the mass of entire hills in the neighbourhood of the

village of Logrosan, in the jurisdiction of Truxillo, a province of Estremadura. The houses and the walls of inclosures are built of it.

## GENUS II.

Earthy Salts with Base of Barytes.

The most common state in which Barytes is found is in combination with the sulphuric acid.

## SPECIES I.

Sulphate of Barytes, Ponderous Spar.

This stone is the most ponderous we are acquainted with. Its specific gravity is commonly from 4 to 4.6.

It decrepitates in the fire, melts before the blow-pipe without addition, and fluxes dissolve it with effervescence.—See the notes of the abbé Mongez\*.

Mr. Darcet succeeded in fusing it in a porcelain furnace.

It has been often confounded with gypsum and fluor spar; but the characters of these two substances are very different.

It almost always accompanies metallic ores, and it is even considered as an happy preface of finding them. Becher has affirmed that it was a certain indication *vel presentis vel futuri metalli*: and I think that there is reason to consider it as the vitrifiable stone of this celebrated naturalist. The proofs of my assertion may be seen in the preliminary ideas of my treatise on metallic substances (in this work). The analogy between this stone and metals has been established by the experiments of Bergmann and of Mr. Lavoisier.

This stone, when rather strongly heated, exhibits a blueish light in the dark. To form these kinds of phosphori, the spar is pulverized, the powder is kneaded up with mucilage of gum tragacanth, and the paste is formed into pieces as thin as the blade of a knife. These pieces

\* Manuel du Mineralogiste.

are afterwards dried, and strongly calcined by placing them in the midst of the coals of a furnace; they are afterwards cleared by blowing on them with the bellows. In this state, if they be exposed to the light for a few minutes, and afterwards carried into a dark place, they shine like glowing coals. These pieces shine even under water; but they gradually become deprived of this property, which however may be restored again by a second heating.—See De Fourcroy.

Ponderous spar is easily divided into plates by the slightest blow; and the most usual form which it affects is that of an hexahedral prism, very flat, and terminated by a dihedral summit.

Ponderous spar has been found at the distance of one league from Clermont d' Auvergne, in the form of hexahedral prisms terminated by a tetrahedral or dihedral pyramid. I have seen crystals of two inches in diameter.

It frequently happens that the form of these crystals is not very determinate; but all the stones of the nature of these exhibit a confused assemblage of several plates applied one upon another, and capable of being separated by a very slight blow. Ponderous spar is insoluble in water; and upon this property is founded the virtue possessed by the muriate of barytes, to manifest the slightest portions of sulphuric acid in any combination which contains it.

Barytes adheres more strongly to acids than the alkalis themselves do; and when the carbonates of alkalis precipitate it, the effect takes place in the way of double affinity.

## SPECIES II.

### Carbonate of Barytes.

This combination has the specific gravity of 3.773.

One hundred parts contain twenty-eight water, seven acid, sixty-five pure earth.

The sulphuric, nitric, and other acids attack it with effervescence.

Although the carbonic acid possesses the strongest affinity with this earth, it is very seldom found in combination with it : and I am acquainted with its existence only on the authority of Mr. Kirwan, who affirms that Dr. Withering presented him with a specimen from Alston Moor, in Cumberland ; which resembles alum, with the difference that its texture is striated, and its specific gravity is 4.331\*.

Mr. Sage analysed this stone, which was presented to him by Mr. Greville.—See the *Journal de Physique* for April 1788.

## SPECIES III.

*Nitrate of Barytes.*

The nitric acid dissolves pure barytes, and forms a salt which crystallizes sometimes in large hexagonal crystals, and frequently in small irregular crystals.

This nitrate is decomposed by fire, and affords oxigene.

The pure alkalis do not disengage the barytes, but the alkaline carbonates precipitate it by double affinity.

The sulphuric and fluoric acids seize this earth from the nitric acid.

It has not yet been found native.

## SPECIES IV.

*Muriate of Barytes.*

This salt is capable of assuming a form considerably resembling that of spar in tables or plates. It exhibits, with the earths, acids, and alkali, phenomena nearly similar to those of the nitrate of barytes.

It forms one of the most interesting re-agents to ascertain the existence of the smallest particle of sulphuric salt in any water ; because, by the sudden exchange of principles, the result is ponderous spar, which immediately falls down.

It has not yet been found in a native state.

\* It is plentifully found in England, in the lead mine of Anglezark, near Chorley in Lancashire. See the *Manchester Memoirs*, vol. iii. p. 598. T.



## GENUS III.

## Earthy Salts with Basis of Magnesia.

These salts were not well known before the time in which the celebrated Black proved that they ought not to be confounded with calcareous salts. They may be distinguished from these by the bitter taste which almost all of them possess.

They are in general very soluble in water. Lime-water precipitates them, as does likewise ammoniac, or the volatile alkali.

## SPECIES I.

## Sulphate of Magnesia, Epsom Salt.

This salt is frequently met with; it exists in several mineral waters, such as those of Epsom, of Sedlitz, &c. It was at first distinguished by the name of the springs which produced it; and it is still known by the name of the bitter cathartic salt, on account of its taste and virtues.

The sulphate of magnesia, in commerce, comes either from the salt springs of Lorraine, from which this salt is extracted with a mixture of sulphur; or otherwise from the salt works in the environs of Narbonne, where it is extracted from the mother waters which contain it abundantly.

The sulphate of magnesia, in commerce, has the form of small silky needles, very white. It does not effloresce in the air, which distinguishes it from the sulphate of soda.

The crystals of the pure sulphate of magnesia are quadrangular prisms, terminated by pyramids of an equal number of sides.

The sulphate of magnesia prepared in our salt works is sold at from thirty to forty livres the quintal; it contains in the pound three sixteenths of sulphate of soda, two sixteenths muriate of magnesia, one sixteenth muriate of soda, six sixteenths true sulphate of magnesia: the rest consists of salts with basis of lime.

The sulphate of magnesia, when exposed to the fire, liquefies, and loses half its weight. The remainder is dry, and requires a strong fire to fuse it.

Water dissolves its own weight of this salt, at the temperature of 60 degrees of Fahrenheit's thermometer.

One hundred parts of this salt contain twenty-four parts acid, nineteen earth, and fifty-seven water.

It exists in all the waters in the environs of Montpellier.

Sometimes it is found efflorescent upon schisti, from which it may be collected. I have found it upon a mountain in Rouergue, in a quantity sufficiently great to be collected to advantage: birds of passage devour it greedily. This salt is used in preference to others as a purgative.

#### SPECIES II.

##### Nitrate of Magnesia.

The celebrated Bergmann, who has combined magnesia with the various acids, observes that the nitric acid forms with it a salt capable of affording, by proper evaporation, prismatic, quadrangular, truncated crystals. The same chemist adds, that this salt is deliquescent. Mr. Dijonval affirms, that he obtained crystals that were not deliquescent; and accident has afforded me a salt of this kind in mother water of nitre concentrated to the 45th degree of the areometer. Its form was that of prisms with four sides, very much flattened, very thick, and very short.

This salt decomposes the muriates; alkalis precipitate its magnesia, as does likewise lime.

#### SPECIES III.

##### Muriate of Magnesia.

The muriate of magnesia exists in the mother water of our salt works; its taste is very bitter.

According to Bergmann, it forms a salt in small needles, so deliquescent that it cannot be obtained but by strongly concentrating the solution, and afterwards exposing it to intense cold.

Lime-water, barytes, and the alkalis precipitate the magnesia; it may likewise be separated by means of fire.

## SPECIES IV.

*Carbonate of Magnesia.*

Though magnesia has the greatest affinity with the carbonic acid, I do not think that nature has ever exhibited this combination. It is obtained by precipitating the magnesia from Epsom salt, by means of the carbonates of alkali; and in this state it is called effervescent magnesia, or magnesia not calcined.

The carbonate of magnesia contains in the quintal thirty parts acid, forty-eight earth, and twenty-two water.—See Kirwan and Bergmann.

Magnesia sticks to the tongue; and assumes, in drying, a certain transparency, which it preserves until it has lost all its water, which is not easily driven off.

Fire carries off the water and the acid; and in this state the residue is called calcined magnesia.

The carbonate of magnesia is soluble in water in the proportion of several grains in an ounce of the fluid.

But we are indebted to Mr. Butini for a very singular observation—that cold dissolves more than hot water, and that the magnesia may be precipitated by heating the water which holds it in solution. Hence it arises that waters loaded with magnesia become white and turbid by ebullition.

The celebrated Bergmann had advanced that the carbonate of magnesia is crystallizable. Mr. Butini, by concentrating a saturated solution of this salt with a gentle heat, obtained groups of crystals, which, when examined by the microscope, appeared to be hexagonal truncated prisms. I have obtained similar snow-like flocks by precipitating magnesia by the addition of an alkali, drop by drop.

The carbonate of magnesia is used in medicine as a purgative. The calcined magnesia ought to be preferred as an absorbent.

## GENUS IV.

## Earthy Salts with Base of Alumine.

The substance which in the arts is known by the name of Clay, is a natural mixture of several earths.

Alumine, or pure clay, is capable of combining with the greatest part of the known acids; but the most common of these salts is alum.

## SPECIES I.

## Sulphate of Alumine, Alum.

Though alum be very commonly met with, yet the combination of principles which constitute it is not effected without considerable difficulty.

Pure clay upon which the sulphuric acid is digested, is dissolved with difficulty; and it is by no means easy to bring this combination to regular crystals. The usual product is a salt, which appears to be formed by scales applied one upon the other.

The most ordinary process to dissolve alumine by means of an acid, consists in calcining the clay, impregnating it with the acid, and facilitating its action by an heat of 50 or 60 degrees of Reaumur. But a simpler method, which I have used in my manufactory of alum, consists in presenting the acid in vapours, and under the dry form, to the clay properly prepared. For this purpose I calcine my clays, and reduce them into small pieces, which I spread over the floor of my leaden chambers. The sulphuric acid, which is formed by the combustion of a mixture of sulphur and saltpetre, expands itself in the cavity of these chambers and exists for a certain time in the vaporous form. In this form it has a stronger action than when it has been weakened by the mixture of a quantity of water more or less considerable: so that it seizes the earths, combines with them, causes them to increase in bulk by the efflorescence which takes place, and at the end of several days the whole surface exposed to the vapour is converted into alum. Care is taken to stir these earths from time to time, that they may successively present all their surfaces to the action of the acid.



But whatever process may be used to combine the acid with clay; it is necessary to expose the aluminized earths to the air during a greater or less space of time, in order that the combination may be more accurate, and the saturation more complete.

Most of the alum in commerce is afforded by ores which are dug out of the earth for this purpose. We may reduce all the operations of this manufacture to three or four; the decomposition of the ore, the lixiviation of the ore, the evaporation of these lixiviums, and the crystallization of the alum.

1. The decomposition of the mineral is effected either in the open air without assistance, or else by means of fire.

When the mineral is left to decompose spontaneously, nothing more is done than to dispose the stone which contains the principles of alum in strata or layers. The pyrites becomes heated; acid is formed, which dissolves the clay; and the salt arising from this combination exhibits itself by the efflorescence of the ore. The decomposition may be accelerated by watering the heap of pyrites; but the operation may be still more abridged by the assistance of fire.—The method of applying the heat varies prodigiously. On this head Bergmann may be consulted; but in general it may be observed that it ought not to be either too strong or too weak. In the first case it volatilizes the sulphur, and in the second it retards the operation.

The ore of alum is sometimes impregnated with a sufficient quantity of bitumen to maintain the combustion.—See my Memoir on the Alum Ore of Vabrais, 1785.

2. When the ore has effloresced into alum, the salt is extracted by lixiviation. For this purpose the same water is passed over several heaps of aluminous earth, in order to saturate it. The water which is first passed over the earth dissolves in preference the vitriol, which is more or less abundant; and this salt may be separated from the alum by a previous cold-washing.

3. This lixivium, or saline solution, is carried into leaden caldrons, where the fluid is properly concentrated. In this part of the process it is that an accurate saturation

of the alum is effected when the acid is in excess; and for this purpose alkalis are added, which serve likewise singularly to facilitate the crystallization. The celebrated Bergmann has proposed to boil clay with the solution, to saturate the excess of acid. This process seems in every point of view to be advantageous; but it appears to me to be impracticable, because the superabundant acid cannot be made to combine with the clay but by a very long ebullition; and I have observed that, by afterwards evaporating the fluid to cause it to crystallize, this clay falls down, and opposes the crystallization. I have varied the process in a variety of ways, without obtaining the success which its celebrated author predicted.

There are methods of greater or less accuracy to judge of the degree of concentration to which it is proper to carry the lixivium; in order to obtain a good crystallization: such are, the immersion of an egg in the liquid, the effusion of some drops of the lixivium on a plate, &c. Mr. De Morveau has proposed a metallic hygrometer; but this instrument cannot be considered as very accurate, because its immersion in the liquid is proportional to the heat of the fluid in which it is plunged.

4. The lixivium is then conveyed into coolers, where it crystallizes by mere refrigeration. The pyramids of alum are constantly turned towards the bottom of the vessel, more especially those which fix themselves to the sticks which are put into the liquor to multiply the surfaces.

Alum affects the form of two tetrahedral pyramids, applied to each other base to base. Sometimes the angles are truncated, and these truncatures take place most frequently when the lixivium is slightly too acid.

This salt requires fifteen times its weight of water to dissolve it, at the temperature of 60 degrees of Fahrenheit, according to Kirwan.

Its taste is styptic; it loses its water of crystallization by heat; at the same time that it swells up, and is converted into a light and white substance, called burned or calcined alum.

If it be urged by a violent degree of heat, it loses part of its acid, and becomes tasteless. The residue is no

longer susceptible of crystallization, and precipitates in the form of a very fine adhesive powder, in proportion as the water is dispersed by evaporation.

Alumine is precipitated from this solution by magnesia, barytes, and the alkalis: these last dissolve the precipitate in proportion as it is formed, if they be added in excess.

Alum is a very valuable material in the arts. It is the soul of the art of dying, and serves as the mordant to all colours. It is used to prepare leather, to impregnate paper and cloths intended to be printed. It is added to tallow, to render it harder; it enters into the preparation of a glue for the destruction of vermin; it is employed in England, and elsewhere, to give whiteness, and additional weight, to bread. When fused with saltpetre of the first boiling, it forms a very white crystal mineral.

The printers rub their balls with calcined alum, to cause them to take the ink. Surgeons employ it to corrode fungous or proud flesh.

#### SPECIES II.

##### Carbonate of Alumine.

The argillaceous earth precipitated from the solution of alum by the carbonates of alkalis, combines with their acid; but this salt is very rarely found in nature. I know only of the observation of Schreber which ascertains its existence. This naturalist asserted that the earth known by the name of Lac Lunæ is a true carbonate of alumine.

Although alumine be soluble in the other acids, we are very little acquainted with its combinations. It is only known that the nitric acid dissolves it, that the solution is astringent, and that it may be obtained in small styptic and deliquescent crystals.

The muriatic acid has a more evident action upon alumine. This muriate is gelatinous and deliquescent.

These salts have not been applied to any use, and they are no where found in nature.

#### GENUS V.

##### Earthy Salts with Base of Silex.

Silex is of all the known earths that which combines the most difficultly with acids.

We are even acquainted with no other acid than the fluoric which exerts an evident action upon it. It rises with it, and holds it in solution until it abandons it to unite with water.

Some experiments of Mr. Achard gave reason to think that the carbonic acid dissolved silex; but the Parisian chemist did not obtain the results announced by the chemist of Berlin. M. De Morveau seems to have proved that iron and the carbonic acid were necessary to form rock crystals: but this acid does not remain united and combined with the earth; so that we have not hitherto arrived at any proof of its dissolving virtue.

#### CLASS II.

Concerning the Combination and Mixture of Primitive Earths, or Earthy Mixtures.

The pure and simple earths, such as we have described them, are rarely found on the surface of the globe. They are constantly mixed with each other, and form masses of greater or less magnitude, and various hardness, according to the nature of the earths, their state of division, and the character of the foreign substances which are combined with them, such as iron, bitumens, &c.

It may be easily understood that the number of compositions which can result from the mixture of five primitive earths, would be infinite, if we were to pay attention to such slight varieties as depend on the proportions of the mixture: but I shall not consider any mixtures as constituting species truly distinct, except such as differ in the identity of their constituent principles. The slight differences in the proportions of these principles may indeed occasion modifications in the form, the hardness, the colour, &c. But these can never constitute more than varieties.

We shall naturally deduce the genus from the stone or earth which predominates in any mixture, and appears to communicate its own character to the total mass. In this manner we shall class among the calcareous mixtures such stones as exhibit to our observation the properties of limestone to such a degree, that they would be taken to be



purely calcareous if the chemical analysis did not prove the existence of other principles.

The genus ought not in strictness to be taken and deduced from the earthy principle which predominates; for the character of the whole mass or of the mixture, is very frequently given by an earth which does not form the most abundant principle; as we observe more especially in magnesian earths, where the flint predominates over the magnesia.

## GENUS I.

## Calcareous Mixtures.

According to the principles we have laid down, we must refer to this place those stony mixtures in which the properties of lime-stone predominate.

## SPECIES I

## Lime-stone and Magnesia.

This mixture is very common; almost all the calcareous stones contain magnesia. Mr. Bayen has described a variety in the *Journal de Physique*, t. xiii. which contain in the hundred parts seventy-five carbonate of lime, twelve magnesia, and thirteen iron: it is the earth of Crentzwald. Mr. Woulfe has described another variety in the *Philosophical Transactions* for 1779. It afforded sixty parts carbonate of lime, thirty-five carbonate of magnesia, and three of iron.

The analyses which I have made of several lime-stones in our province, constantly afforded magnesia.

## SPECIES II.

## Lime-stone and Barytes.

Mr. Kirwan has informed us that this species is found in Derbyshire, in the form of a stone, and likewise in the earthy state. It is of a grey colour, and harder than ordinary lime-stones.

## SPECIES III.

## Carbonate of Lime and Alamine.

This mixture is frequently met with. It is commonly known by the name of Marle. The proportions of the

two constituent principles are infinitely various. It is upon this proportion that the distinction of fat marles and lean marles depends, and disposes them to serve as manure for earths of different kinds. The marles are almost always coloured by iron.

They appear to arise from the decomposition of the natural mixtures of chalk and clay, and contain more or less of silex; but the analysis which I made six years ago of all the marles I could procure, convinced me that they were often nothing more than a mixture of clay and chalk. I have likewise found magnesia in marles, sometimes in the quantity of seventeen parts in the hundred; but, in general, they may be considered as formed essentially by the two earths here mentioned.

Alumine is found likewise mixed with carbonate of lime in marbles. Mr. Bayen has proved this in the second volume of the *Journal de Physique*: and I have confirmed the truth of his results by the analysis of several marbles of our province. It is even upon this principle that we may account for the greasy polish which some of them take.

The very evident difference which may be established between the mixtures which form marle and marble, is, that the first is the immediate product of a decomposition principally effected by the alterations of the iron which it contains; whereas, the second is produced by a purely mechanical mixture of two principles already formed, which being pounded, and ground as it were together, form a compact, hard, close assemblage, susceptible of the most beautiful polish.

#### SPECIES IV.

##### Lime-Stone and Silex.

This species is not common. It is known under the name of *Stellated Spar*, *Stern Schoerl* of the Germans. It is opaque, of a radiated texture or form. Mr. Fitchel found it in lime-stone on the Carpathian mountains. It effervesces with acids; and, according to Mr. Bindheim, one hundred parts of this stone contain sixty-six carbonate of lime, thirty silex, and three iron.—See Kirwan.

The mixture of the pulverulent remains of the primitive rocks transported into our country by the rivers which rise in the Alps and the Cevennes, together with our own calcareous fragments, frequently form beds of a stone of this nature. The only difference between them is, that our mixtures exhibit a confused assemblage of all the principles which belong to the primitive rocks, such as clay, flint, and others.

## SPECIES V.

## Limestone and Bitumen.

This mixture is known by the name of Swine-stone. It abounds in the dioceses of Alais and Uzes: I have seen the calcareous rock impregnated with bitumen in an extent of more than three leagues diameter. It is even so abundant in some parts, that it distils through the clefts of the rocks, and forms stalactitious bitumen, which the peasants collect to mark their sheep, or to grease their cart-wheels. The heat of our summer sometimes softens it to such a degree, that it flows into the roads, where it adheres to and impedes the motion of the sledges and other carriages.

In some places the stone is so well impregnated with bitumen, that it may be wrought; but the blow of a hammer causes it to emit an abominable smell. Mr. D'Avejan, bishop of Alais, having used this stone to pave the apartments of his palace, the friction and heat disengaged so unpleasant a smell, that his successors were obliged to substitute a stone of another kind in its stead.

Mr. De la Peyrouse found this stone in large masses near Saint Beal in Comminge, at L'Estagneau, and the mill of Langlade.

## SPECIES VI.

## Lime-Stone and Iron.

Iron is almost always a constituent part of lime-stone; but it sometimes exists in such a proportion, that these mixtures constitute iron ores. Mr. Kirwan describes two of this nature; one of which contains twenty-five pounds of iron in the quintal, and the other ten. Mr. Rinmann

has described stalactites which afford iron, in the proportion of from twenty-seven to twenty pounds in the quintal.

Calcareous iron ores are wrought in many parts of our province. I have myself obtained forty-four pounds of iron in the quintal, from a calcareous stone which abounds on the mountain of Frontignan.

It is common to find, in our calcareous mountains, hematites rich in iron, whose base is calcareous; we find likewise species of ludus of the same genus, and sometimes even tufa, whose formation arises from waters loaded with iron and lime.

The spathose iron ores are of the same class as those we have just treated of.

## GENUS II.

### Barytic Mixtures.

These mixtures are very rare, because the stone itself is scarce. We shall mention only two species.

## SPECIES I.

Sulphate of Barytes, Petroleum, Gypsum, Alum, and Silix.—Bergmanni Sciagr. f. 90; Kirwan Min. p. 60.

The name of Hepatic Stone (*Lapis Hepaticus*) has been given to this mixture.

The colour varies much: its texture is uniform, lamellated, scaly, or sparry. It takes the polish of alabaster.

It forms a kind of plaster by calcination, and emits a strong and fetid smell by friction.

One hundred parts of this stone contain thirty-three barytes, thirty-eight silix, seventeen alum, seven gypsum, and five petroleum.

## SPECIES II.

### Carbonate of Barytes, Iron and Silix.

Mr. Kirwan has mentioned this stone on the authority of Mr. Bindheim. It is insoluble in acids, and of a sparry texture; but he is tempted to consider it as a sulphate of barytes, in consequence of the property observed by Mr. Bindheim, that it becomes soluble in acids, after having been calcined with oil.



GENUS III.

Magnesian Mixtures.

All the species comprised in this genus possess characters sufficiently striking, and easily known. They are in general greasy and soft to the touch; they may be cut with a knife, turned in a lathe, and converted into any form at pleasure. They take a tolerably good polish. Some of them are disposed into fibres; and these fibres possess for the most part, a remarkable degree of flexibility. They stick to the tongue like clays; but do not, like them, soften in the water.

SPECIES I.

Pure Magnesia, Silix, and Alumine.

SPECIES II.

Carbonate of Magnesia, Silix, and Alumine.

The mixture of these three earthy principles forms talcs, steatites, pot-stones, or lapides ollares.

The difference which analysis shews between these two species, is almost entirely confined to the proportions of their constituent principles. This circumstance might appear sufficient to authorise us in considering them only as varieties of each other. But as the magnesia is pure in the talc, and in the state of carbonate in the steatites, we shall consider them as different species.

1. Pure magnesia, mixed with near twice its weight of silix, and less than its weight of alumine, forms talc. It is of a white, grey, yellow, or greenish colour; soft and soapy to the touch, composed of transparent laminæ placed upon each other. These laminæ are more tender than those of mica; they lock together, and are usually divided into rhombi, and may be crushed or scratched with the nail.

Its specific gravity is 2.729.

Fire renders it more brittle and white; but it is infusible by the blow-pipe, and can scarcely be fused by the

addition of alkali. The borate of soda, and the phosphate of urine, fuse it with a slight effervescence.

Muscovy talc is composed of large elastic, flexible, and transparent leaves. Plates of talc have been raised in the quarries of Vitim in Siberia which were eight feet square.

2. Steatites is usually of a greenish white: it may be easily cut with a knife; and the dust which is produced by scraping it does not readily mix with water.

Its specific gravity is about 2.433.

It is infusible alone, hardens in the fire, and becomes white. The borate of soda facilitates its fusion; but soda, and the phosphates of urine, do not perfectly dissolve it.

According to the analysis of Bergmann, one hundred parts of steatites contain eighty six, seventeen magnesia, in the state of carbonate, two alumine, and one iron.

Steatites is sometimes found in masses of indeterminate figure, and sometimes crystallized, such as that which Mr. Gerhard found at Raichewtein in Silesia. Chem. Ann. 1785.—And Mr. Romé de Lisle possesses crystals in hexagonal laminae resembling the leaves of mica.

The white steatites of Briançon is composed of irregular, friable, and semi-transparent leaves. It often incloses crystals of steatites, of a white or greenish colour, which have the form of tetrahedral prisms.

The steatites of Corsica appears to be formed by fibres placed beside each other. It has a greenish colour, and no perceptible degree of flexibility.

The steatites of Barcith is grey, compact and solid.

That of Queen Charlotte's Bay in New Zealand is striated, green, semi-transparent, and sufficiently hard to give fire with the steel.

3. The soap-stone of China is a steatite, often striated; but it is not more unctuous than those we have already mentioned.

The steatites of Briançon forms the basis of the vegetable red.

4. The lapis ollaris, or pot-stone, is only a variety of the steatites. It does not appear to me to differ from it, excepting in being harder.

Its colour is usually greyish ; but it is sometimes blackened by bitumen.

Mr. Gerhard has observed that the lapis ollaris of Sweden effervesces with acids, and contains calcareous earth ; but this mixture is peculiar to it. Those of Saxony, Silesia, and Corsica do not contain it. The lapis ollaris may be wrought with the greatest facility. In the country of the Grisons, in Corsica, and elsewhere, it is turned, and formed into vessels which resist the fire, and have not the inconvenience of our glazed pottery ; it is from these uses that it has obtained the name of Lapis Ollaris, Pot Stone, &c.

### SPECIES III.

Pure Magnesia combined with somewhat more than its weight of Silix, one-third of Alumine, near one-third of Water, and more or less of Iron.

This mixture forms the serpentine. It has a great analogy with the preceding substances, but is distinguished from them by a more evident degree of hardness ; by the property of acquiring a more beautiful polish ; and by a quantity of iron sufficiently considerable to afford it a peculiar character.

The serpentine is whitish, greenish, blueish, or blackish ; frequently marked with black spots ; and sometimes intersected with bands of various colours. Some serpentines are even transparent. The Royal Cabinet of Mines possesses a specimen whose ground is grey, and interspersed with reddish semi-transparent and chatoyant spots.

Serpentine varies likewise in its texture.

It is compact, granulated, scaly, lamellated, or fibrous. It takes the most beautiful polish.

The iron it contains is sometimes obedient to the magnet.

Its specific gravity is from 2.4 to 2.65.

It melts in a violent heat ; but a less degree of fire hardens it.

Mr. Bayen, who has analysed the serpentine, found it to contain, in the hundred parts, forty-one silix, thirty-three magnesia, twenty alumine, three iron, and also water.

Mr. Kirwan has observed, that the serpentine of Corsica, contained more alumine, and less silix.

Mr. De Joubert possesses a species of serpentine which exhibits square plates on its surface.

Mr. Dorthes has observed several varieties of the serpentines on our Mediterranean coasts, and in the river of Herault, which receives them from the mountains of the Cevennes.

## SPECIES IV.

Carbonate of Magnesia; Silex, Lime, Alumine, and Iron.

This combination exhibits several varieties, which are known under the name of Asbestos, Mountain Cork. Their texture serves to distinguish them; but the chemical analysis confounds them together, and does not permit us to allow any other distinction than that of varieties.

## VARIETY I.

## Asbestos.

This stone is usually greenish; its texture is sometimes fibrous and compact, and sometimes membranaceous.

Near Bagnères de Bigorre, in the mountains of the environs of Bassiere, Messrs. Dolomieu and La Perouse found crystals of asbestos in rhomboidal parallelepipeds.

Asbestos is rough to the touch, brittle and rugged. Its specific gravity is from 2.5 to 2.8.

Fire renders it whiter and more brittle. It is infusible by the blow-pipe, according to Kirwan; but the abbé Mongez affirms that asbestos and amianthus are fusible, and form an opaque globule, which becomes blueish. It is difficultly soluble with soda; but more easily with borate of soda and the phosphates of urine.

According to Bergmann, the asbestos contains in the quintal from fifty-three to seventy-four parts silice, about sixteen magnesia, from twelve to twenty-eight carbonate of lime, from two to six alumine, and from one to two iron.

## VARIETY II.

## Mountain Cork.

This name has been given on account of a slight resemblance of this substance to cork. This stone is very light,



membranaceous, flexible, and usually of a yellow colour. It may be more easily torn than broken. The diocese of Alais affords very fine specimens.

Among a very great number of stones of this nature; subjected to analysis by the celebrated Bergmann, the siliceous earth was always found predominant; and after that the magnesian, which was never less than twelve parts in the hundred, nor more than twenty-eight.

## SPECIES. V.

Carbonate of Magnesia and Lime, Sulphate of Barytes, Alumine, and Iron.

This combination forms amianthus. It is composed of long flexible fibres, parallel to each other, and very soft to the touch.

They are sometimes very white, but often yellowish. The filaments may be separated and detached from each other; and may be even twisted in any direction without danger of breaking them. Their flexibility is so wonderful, that they may be formed into cloth. The ancients constructed cloths of this kind, in which they burned the bodies of the dead; and by this means the ashes were collected without mixture of those of the fuel.

Mr. Dorthes found amianthus in tufts upon calcareous stones thrown up by the sea, on which it was fixed with plants, corallines, gorgonia, &c. He believes, with reason, that this amianthus did not originate upon the stones, but that it was deposited by the water. He found likewise, on the coast, balls of the amianthus of two or three inches diameter imitating ægagropiles, and formed by the intertwining of the threads of amianthus; and covered with a white tophose substance, of the nature of that which covers the gorgonia, and is the work of a species of sea animalcule.

The fibres of amianthus are of various lengths. I have received specimens from Corsica, whose filaments were very flexible, and eight inches long. That from the Pyrenean mountains has shorter fibres.

Bergmann analysed an amianthus from the vicinity of Tarento, of which 100 parts afforded 64 filix, 18.6 magnesia, 6.9 lime, 6 fulphate of barytes, 3.3 alumine, 1.2 iron.

#### GENUS IV.

##### Aluminous Mixtures.

Argillaceous or aluminous stones are common enough. They are seldom possessed of more than a moderate degree of hardness, and are divisible in water. But the mixture of their principles is in some instances so intimate, that they possess a very strong degree of consistence.

#### SPECIES I.

Alumine, Silix, Carbonate of Lime, and more or less of Iron

We may here place all the varieties of clay. Chemical analysis exhibits, constantly enough the principles whose mixture forms this species; but the proportions among these constituent principles vary so much, that the varieties of clay are almost infinite. Independent of the principles above enumerated, we sometimes find lime combined with clay, and sometimes even magnesia; and it will be easy to form various species, in proportion as the analysis of these earths shall become more perfect.

The argillaceous mixtures of which we propose at present to speak, are characterized by the following properties:—They adhere strongly to the tongue, become dry, hard, and shrink in the fire; are divided, and form a paste, with water, in which state they may be easily moulded and turned, &c. The clays in which the siliceous principle is most abundant are the driest, adhere less to the tongue, are less completely diffused in water, and crack less when dried by the heat of the fire or the sun.

Most clays contain iron; and this metal is usually the principle of their colour. From the brownish clay, in which iron is almost in the native state, to the deepest red, all the various shades are owing to the several degrees of alteration in this metal. These various changes are

effected either at the surface of the globe by the immediate action of the air, which calcines the iron, or else in the bowels of the earth; in which last case, the effects arise from the decomposition of water and of the pyrites. We may trace this beautiful work of nature in several pyritaceous strata in our province; and on this subject reference may be had to my Memoir upon the Brown Red (*Brun Rouge*), printed by Didot by order of the province.

We shall direct our attention less to the several varieties of clay than to the uses to which they are applied. The first of these uses is to form the basis of pottery.

Several species of pottery may be observed, which nevertheless differ from each other only in the degree of fineness of the earths made use of, and the care that has been taken in performing the various manipulations which they undergo.

1. The most common pottery is made with any kind of clay indiscriminately, which is mixed with sand, to render it more porous, and by this means more adapted to support the heat.

These vessels would be penetrable by water, if they were not covered with a glaze.

The glazes of pottery are usually made either with the sulphureous lead ore called *Alquinfoux*, and in England, *Potters Lead Ore*, or with the yellow copper ore. For this purpose, these substances are reduced to powder, mixed with water, and the vessel, previously dried by a slight baking, is dipped in the mixture. The porous vessel absorbs the water, while its surface becomes covered with the pounded ore. The vessel is then carried to the furnace, and baked by a heat which vitrifies the ore upon its surface: and it is this metallic glass which forms the glaze of the potters, and is yellow or green, according to the metal made use of.

These glazes are all dangerous; because they are soluble in fats, oils, acids, &c.

The attention of intelligent manufacturers has been long directed to the methods of substituting in the place of



these glazes, others which are not attended with the same danger.

We might, after the manner of the English, vitrify the surface of our pottery by means of sea salt thrown into the fire-place when the furnace is at a white heat; but this method is impracticable in most of our manufactories, because our fires are not sufficiently strong.

I have tried various methods to glaze pottery; and two among them have succeeded well enough to justify my publishing them. The first consists in mixing the earth of Murviel in water, and dipping the pottery therein: this done, they are suffered to dry; after which they are plunged into a second water, in which levigated green glass is mixed. This covering of vitreous powder fuses with the clay of Murviel; and the result is a very smooth, very white, and very cheap glazing.

The second method consists in immersing the dried pottery into a strong solution of sea salt, and afterwards baking them. The trial which I have made in my furnaces gives me reason to expect that this method may be used in large works.

I have likewise obtained a very black glazing, by exposing pottery strongly heated to the fumes of sea-coal: I have coated several vessels in this manner, by throwing a large quantity of coal in powder into a furnace wherein the pottery was ignited to whiteness. The effect is still more complete when the chimneys or tubes of aspiration of the furnace are at that moment closed, and kept so for some minutes.

I have given an account of all these circumstances, and many others, in a work presented to the Royal Society of Sciences of Montpellier; in which I have proved, from the results of my experiments in the large way, that the best mixture of our own earths is capable of affording us the most beautiful and finest pottery of every kind.

2. Fayence\*. This does not differ from the pottery we have here spoken of, except in the degree of fineness

\* Distinguished by us by the name of Delft Ware. T.



of the earths used for its basis, and the nature of its covering or glaze.

The glazing of fayence is nothing else, as is well known, but glass rendered opaque by means of the oxide of tin. It is the glass called Enamel.

To make the fine white enamel of the potters, one hundred pounds of lead, thirty of tin, ten of marine salt, and twelve of purified pot-ash, are calcined together. This mixture, after calcination and fusion, produces a beautiful enamel, which is applied in the same manner as the glaze before spoken of.

Bernard de Palissy excelled in the art of fayencery; and it is to him that we are indebted for our first acquisitions in this manufacture\*.

\* I cannot resist my inclination to insert in this place a few circumstances of the life of this great but unfortunate man, who lived in the 15th century. He was a native of the diocese of Agen, and his first employment was that of surveyor or draftsman of plans: but his taste for natural history led him to abandon this employment; and he travelled for instruction over the whole kingdom, and Lower Germany. An accidental circumstance threw into his hands a cup of enamelled pottery; and, from that time, his whole time and fortune were taken up in experiments on enamels. Nothing can be more interesting than the narrative which he himself has given of his labours. He exhibits himself building and rebuilding his furnaces; always on the eve of success; worn out by labour and misfortune; the derision of the public; the object of the angry remonstrances of his wife; and reduced to burn his furniture, and even the wood-work of his house, to keep his furnace going. His workman presses him for money: he strips himself, and gives him his clothes. But at length, by dint of indefatigable labour, constancy, and genius, he arrived at the desired degree of perfection; which gained him the esteem and consideration of the greatest men of his age. He was the first who formed a collection of natural history at Paris, and even gave lectures on that science; receiving half a crown from each of his auditors, under the obligation of returning it fourfold if any thing he taught should prove false. The high reputation he acquired, and the obligations under which his countrymen stood indebted to him, were not sufficient to defend him from the persecutions of the League; for Matthew De Launay, one of the greatest fanatics, caused him to be dragged to the Bastille at the age of ninety years. He signalized himself in his prison by acts of firmness and heroism. Henry the Third visited him, and represented his situation in these words: "My good man, if you cannot reconcile yourself to the matter of religion, I shall be compelled to leave you in the hands of my

3. The finest pottery is known by the name of Porcelain; it ought to be white, transparent, and of a fine grain.

The first porcelains were manufactured in Japan and China.

The celebrated Reaumur first undertook a capital series of experiments to imitate these potteries: but, deceived by the semi-transparency and vitreous appearance of porcelain, he imagined it to be a semi-vitrification, and attended only to the means of stopping the process of vitrification at a certain stage of its effect, or of causing it to become reversed. He succeeded in his undertaking, by filling bottles with sand and gypsum, and exposing them to a potter's furnace. I have likewise produced the same effect by a very different process, though dependent on the same theory. When I concentrate my oil of vitriol in the green glass of our manufacture, that part of the retort which is continually struck by the rising oil of vitriol becomes white, and loses its transparency. This phenomenon constantly takes place, whenever the fire is raised somewhat more than usual. The retort preserves its form; but all its alkali is extracted, and there remains only the quartzose principle of a beautiful white colour, somewhat cracked like the porcelain of Japan. As the decomposition commences at the interior surface, which is immediately acted on by the vapours, this surface is frequently

"enemies,"—Palissy answered, "Sire, I was perfectly ready to surrender my life for the glory of GOD. If this action could have been accompanied with any regret, certainly it must have vanished after hearing the great King of France say, *I am compelled*. This, Sire, is a situation to which neither yourself, nor those who force you to act contrary to your own disposition, can ever reduce me: because I am prepared for death; and because neither your whole people, nor your Majesty, possess the power of forcing a simple potter to bend his knee before images."—Bernard De Palissy, was the first who assumed that calcareous mountains are the remains of shells. He has exhibited such a degree of intelligence and sagacity in all his writings, that he deserves to be placed among those great men who are an ornament to our nation. The very form of his works exhibits a proof of original genius. They consist of dialogues between Theory and Practice. Practice is always the instructor; and Theory is represented as a scholar, proud of his own understanding, but indocile and ignorant.

rendered white, and discoloured; while the exterior surface remains perfectly vitreous, and exhibits a striking contrast. For, when the interior surface of the glass is inspected, it presents a white covering applied against a surface of glass; forming, by the union of both, a thickness no greater than that of which retorts are usually made.

Father Dentrecolles sent from China the substances used in the fabrication of porcelain: they are known by the names of Kaolin and Petunzé. Similar substances were soon found in France; and our porcelain manufactories, in a short time, equalled the most beautiful productions of this kind, and even exceeded them in the beauty of design and figure. The manufactory of Sèvres is at present, without contradiction, the first in the world. Nothing can equal the beauty of its paintings, the regularity of design, and the elegance of form, which are given to the vessels produced in this manufactory.

Four principal operations may be distinguished in the manufacture of porcelain.—1. The preparation, the mixture of earths, and the working of the paste. 2. The first baking, which forms the biscuit. 3. The application and fusion of the glaze and covering. 4. The art of painting, which demands a third baking, in order that the colours may be better combined, fused, and amalgamated with the glaze.

I have myself made very beautiful porcelain with the kaolin, which is found in veins in the granite of St. Jean de Gardonenque, and the field spar so common in our mountains of Cevennes.

The quantity of porcelain which is made in China is immense. There are five hundred furnaces, and near a million of men, employed at King-to-ching, a province of Kian-si.

Our clays possess other advantages likewise: they serve, in the fulling-mills, to clean and full piece goods. The best fullers earth is soft and soapy.

The name of tobacco-pipe clay is given to a white clay, which preserves its whiteness in the fire, and resists a violent heat.

The scaled earths, or *terræ figillatæ*, are clays upon which superstition has bestowed chimerical virtues. They



are impressed with a seal, for the purpose of deceiving the public with greater certainty and effrontery.

Almost all the marles, more especially those which are found in strata, appear to me to be composed of the same principles. Much variation prevails with respect to the proportion of those constituent principles, and more especially with regard to the clay which predominates.

## SPECIES II.

Alumine, Silice, Pure Magnesia, and Iron.

Mica, which results from the mixture of these principles, has been improperly confounded with talc. Mica is soft to the touch, but not greasy like talc. It possesses in general a more brilliant and less earthy colour, if I may use these expressions.

The most usual colour of mica is white or yellow, inclining to red; but it has been found of a greenish, red, brown, and other colours.

Its texture likewise varies: it is scaly, lamellated, or striated.

It sometimes exhibits the form of a segment of an hexagonal prism.

It is usually found mixed with feld spar, quartz, schorl, &c. It almost always exists in the primitive rocks. Its specific gravity is from 2.535 to 3.000 when charged with iron.—Kirwan.

The colourless mica is infusible. It is only partially soluble in soda, in which it becomes divided with effervescence: it fuses in the borate of soda, and in the phosphate of urine, with scarcely any effervescence.

The coloured micas are fusible.—See De Saussure.

The fragments of mica are employed, under the name of Cats Gold or Silver, according to the colour, as a sand for drying ink upon paper.

Its yellow colour, which considerably resembles that of gold, often deceives the ignorant, who suppose that they have discovered a mine of this precious metal when they find a few pieces of this stone.



Mr. Kirwan obtained from one hundred parts of colourless mica, thirty-eight silex, twenty-eight alumine, twenty magnesia, and fourteen oxide of iron.

## SPECIES III.

Alumine, Silex, Magnesia, Lime, and Iron.

The mixture of these principles forms the horn-stone, or horn-blende of the Germans. This stone has a close grain, is difficultly pulverized, and is slightly flattened under the hammer.

Its colour varies which is either black or of a greenish grey; and its texture is in general either lamellated or striated.

Its general characters are, partial solubility in acids without effervescence; a degree of hardness which never amounts to that of affording fire with the steel; a specific gravity never less than 2.66, and frequently as high as 3.88; a strong earthy smell, which it emits when breathed upon, or is moistened with hot water; a tenacity under the pestle, &c.—See Kirwan, who distinguishes two varieties.

## VARIETY I.

Black Horne-stone, Lapis Corneus Nitens Wallerji.

Its texture is either lamellated or grained. In the first case it is sometimes so soft as to be capable of being scratched with the nail. Its surface is frequently of a shining, greasy appearance; and its specific gravity is from 3.6 to 3.88.

Mr. Kirwan found that the lamellated sort contains thirty-seven parts silex, twenty-two clay, sixteen magnesia, two lime, and twenty-three oxide of iron.

## VARIETY II.

Horn-stone of a Greenish Grey Colour.

This variety is either of a granulated or striated texture. Mr. Kirwan found its specific gravity to be 2.683; it is harder than the preceding.

The pale greenish hone is of this quality. Its grain is close; it emits an earthy smell, does not effervesce with acids, nor strike fire with steel. It contains, according to Kirwan, sixty-five parts of silex to the hundred, and its specific gravity is 6.664.

## SPECIES IV.

Alumine, Silex, Carbonate of Magnesia, and of Lime with Iron.

This species, which comprehends the slate or schistus, does not appear to differ essentially from the preceding, since its principles are the same, and there is no other difference excepting what depends on the state of the lime and magnesia; which in this last effervesces slightly with acids, according to Kirwan.

The slate is an argillaceous stone, whose principal character is that of being divisible into very thin plates, capable of being wrought, and of receiving a certain polish.

The colour of the slate is blue, of several degrees of intensity; but this colour varies, and exhibits the following shades.

## VARIETY I.

Blueish Purple Slate.

This is brittle, and of a lamellated texture; does not give fire with the steel; its specific gravity is 2.876; it affords a very clear and silvery sound, when divided into plates of an uniform thickness; it slightly effervesces with acids when it is reduced into powder, but not else.

It forms black scoriæ in a strong fire. Soda assists its fusion, and it is fused still more easily with the borate of soda.

From one hundred grains of this slate Mr. Kirwan obtained forty-six silex, twenty-six alumine, eight magnesia, four carbonate of lime, and fourteen iron.

Slates are used to form tablets, and to cover the roofs of houses.

## VARIETY II.

Black Slate.

This receives a considerable fine polish when rubbed. The powder which is detached is white, and slightly effervesces with acids.

VARIETY III.

Blue Slate.

The blue slate contains less iron than the first variety. It is usually hard, and of a very fine grain.

VARIETY IV.

Slate of a Pale White Colour.

It is less martial than the other varieties, and is more difficultly vitrified.

Slates are used to form tablets, and to cover the roofs of houses.

SPECIES V.

Alumine, Silix, Pyrites or Sulphure of Iron and Carbonate of Lime and of Magnesia.

The schistus which results from this combination is known by the name of Pyritous Schistus.

The pyrites are sometimes dispersed in the mass, in the form of cubical crystals. Sometimes they are discovered only by analysis, or by the spontaneous decomposition of the stone.

The mountains which afford these schisti appear to me to be marine depositions. Impressions of leaves, of fishes, and other characters, are frequently observed, which leaves no doubt of their origin.

The pyrites soon effloresce when the concurrence of air and water assists their decomposition; and the results then are sulphuric salts, with bases of magnesia, alumine, iron and lime. When the sulphate of alumine predominates, it is called aluminous schistus. Most of the alum ores wrought in Europe are of this nature. We have several in Provence which might be wrought; the schisti of Vebron in the Gevandan, those of Curvalle in the Albigeois, afford much alum by their decomposition.

When the magnesian principle prevails, the efflorescence consists of Epsom salt. I have discovered a mountain of this kind in Rouergue, in the neighbourhood of Saint Michael.

These efflorescences of alum or Epsom salt are always more or less abundantly mixed with the sulphates of iron

and of lime; because the sulphuric acid, which is formed by the decomposition of the pyrites, attacks and dissolves all the principles contained in the schistus.

The decomposition of these pyrites may be hastened by exposure to air, calcination, &c.

#### S P E C I E S VI.

Alumine, Silex, the Carbonates of Lime and of Magnesia, the Sulphure of Iron, and Bitumen.

This schistus does not differ from the foregoing, excepting in consequence of its being impregnated with bitumen. It is usually of a black colour, which it owes to its bituminous principle. Its consistence is various; it is sometimes divisible in flakes, and, its surface is either smooth or rugged.

These are the schisti which usually form the focus of volcanos. When their decomposition is favoured by air or water, a prodigious heat is excited, hydrogenous gas is produced, which exerts itself against the surrounding obstacles, and takes fire when it comes in contact with the air. It is this intestine labour which occasions the shocks and tremulous agitations that precede the eruptions of volcanos. The action of volcanos must be more lasting and terrible, in proportion as the quantity of aliment and the focus are the more considerable.

We might, in strictness, place the pit-coals here, as they do not differ from this schistus but in their greater abundance of the bituminous principle. We daily observe spontaneous inflammation to take place in heaps of pyritous coal, and the same effect happens even in the midst, of the veins which are wrought. Several examples of this may be pointed out in the kingdom of France. There even exists at Cransac in Rouergue a true burning volcano. The mountain which contains the coal is prodigiously hot, and flames are perceived from time to time on its summit, which issue from its bowels. All these phenomena depend on the same cause; and from the small artificial volcano of Lemery, to the terrible eruptions of Vesuvius, there is no other difference than what consists in the magnitude of the cause.



When the earthy and metallic principles which form the basis of bituminous schists, are strongly heated, and almost vitrified by the fire which produces their decomposition, they constitute volcanic products.

SPECIES VII.

Alumine, Silica, Lime, and Water.

This stone which is called Zeolite, was unknown to mineralogists before the celebrated Cronstedt gave a description of it.

It is usually of a semi-transparent white; but this colour is sometimes altered by metallic mixtures, and then it assumes all kinds of tinges.

The name of Zeolite has been given to it on account of its property of forming a jelly with acids. This property has even been considered as exclusive and characteristic. But Mr. Swab has very justly observed, in the year 1758, that all zeolites do not possess this property; and Mr. Pelletier has proved in the twentieth volume of the *Journal de Physique* that this property is not even peculiar to zeolites.

The existence of zeolites in certain lavas has induced some naturalists to consider them as produced by the decomposition of volcanic earths.

The most beautiful zeolites come to us from the islands of Ferroe near Iceland. The form of this stone is constant. The radii which compose it diverge as it were from a central point, and are disposed after the manner of a fan. The radius which terminates at the external surface, is found to exhibit a trihedral or tetrahedral pyramid.

The white zeolite affects two principal forms, the cube, and the tetrahedral prism, sometimes flattened, and terminated by an obtuse tetrahedral pyramid.

Its specific gravity is from 2.1 to 3.15.

The zeolite, exposed to a strong heat, dilates, and swells more or less, according to the proportion of water it contains, and at length melts into a porous scoria. Soda fuses with it with effervescence; the borate of soda dissolves it more difficultly; and the phosphates of urine have scarcely any action upon it.

Bergmann obtained from one hundred parts of the red zeolite of Adelfort, 83 flex, 9.5 alumine, 6.5 pure lime, and 4 water.—*Letters on Iceland*, p. 370.

The white zeolite of Ferroe contains, according to Pelletier, fifty flex, twenty alumine, eight lime, and twenty-two water.—*Journal de Physique*, t. xx.

Meyer obtained from a radiated zeolite 51.33 flex, 17.5 alumine, 6.66 lime, 17.5 water.

Mr. Kirwan rightly observes, that the crystallized species contain more water than the others.

#### GENUS V.

##### Siliceous Mixtures.

We shall place in this genus all the stones which give fire with the steel.

#### SPECIES I.

Silex, Alumine, Lime, and Iron intimately combined.

The mixture of these several earths forms the precious stones or gems. All the varieties of gems depend on their colour, hardness, brilliancy, weight, the proportion of their constituent parts, and their more or less intimate combination.

The numerous experiments of the celebrated Bergmann on precious stones, have thrown the greatest light on their nature and composition. The analyses of Messrs. Gerhard, Achard, &c. by exhibiting a strict identity of principles, have confirmed to us the results of the famous Swedish chemist; and it appears that no reasonable doubt can now be formed against those principles.

As gems or precious stones are distinguished in commerce by their colour, we shall preserve this established distinction.

#### DIVISION I.

Red Gems or Precious Stones—the RUBY, GARNET, &c.

1. The ruby is a precious stone of a fiery red colour, electrical by friction, giving fire with the steel, the most ponderous and the hardest of precious stones. It crystallizes in long hexahedral pyramids applied base to base, without an intermediate prism.

Its specific gravity is from 3.18 to 4.283. It is not vitrified in the fire without addition; and even resists the

action of the burning mirror. Flame urged by vital air easily fuses it. It does not lose its colour at the degree of heat which is sufficient to melt iron. The borate of soda and the phosphates of urine fuse it.

One hundred parts of ruby contain, according to Bergmann, forty alumine, thirty-nine silice, nine lime, and ten iron.

The lapidaries, with whom hardness and transparency are the principal characters of stones, distinguish rubies of different colours; and the inhabitants of Pegu, who consider the modifications of the colouring principle as different degrees of maturity, confound the topaz and the sapphire under the name of rubies, of which they make three varieties.

The name of Spinnelle ruby, or Balais ruby, is given to the same kind of stone, accordingly as its colour is of a pale or a deep red. This ruby crystallizes in octahedrons and has a less specific gravity than the oriental ruby.

2. The garnet is transparent when it is not over-loaded with iron. It is in general obedient to the magnet, and of a yellowish red. The forms of the garnet appear to be derived from the rhomboidal parallelopiped, terminating in six equal rhombuses.

They vary prodigiously in colour, and these varieties are—1. The red, or the carbuncle of Theophrastus, according to Hill: it has a deep red colour. 2. The Syrian garnet, of a deep red slightly tinged with yellow. 3. The violet garnet, of a beautiful red mixed with violet.

All the garnets, whether denominated oriental or accidental, rank in one of these three classes.

Garnets change in the fire into an enamel of a blackish red. They are strongly attacked by the borate of soda, and the phosphates of urine.

Garnet is found in small grains in sand stone (gres) or in schistus.

The texture of the garnet is lamellated, and its fracture vitreous.

Its hardness is inferior to that of other gems, but it exceeds that of rock crystal.

Its specific gravity is from 3.6 to 4.188.

One hundred parts of garnet contain, according to Mr. Achard, 48.3 flint, 30 clay, 11.6 lime, 10 iron.

They sometimes contain tin, or even lead; but this is seldom.—Bergmann.

## DIVISION II.

Yellow Gems or Precious Stones—the TOPAZ, the HYACINTH, &c.

1. The topaz is of a gold colour. — We are acquainted with two principal varieties: the occidental or Brazilian topaz, which has the beautiful deep yellow colour of gold; and the oriental, whose colour is lighter. The Saxon topaz resembles the latter.

The oriental topaz loses neither its colour nor its transparency in the porcelain furnace. The Brazilian topaz loses its polish, its hardness, and its transparency, but without melting.

The oriental topaz affects the octahedral form.

The Brazilian topaz crystallizes in rhomboidal tetrahedral prisms, grooved longitudinally. They are terminated by two tetrahedral pyramids with smooth triangular faces.

The Saxon topaz exhibits long suboctahedral prisms, terminated by hexahedral pyramids more or less truncated at their base.

The specific gravity of the oriental topaz is to that of water as 40,106 to 10,000; that of the Brazilian topaz is as 35,365 to 10,000.—See Brisson.

The analysis of one hundred parts of topaz afforded Bergmann forty-six clay, thirty-nine flint, eight carbonate of lime, and six iron.

2. The oriental hyacinth is of a reddish yellow colour.

It is usually crystallized in the form of a rectangular tetrahedral prism, terminated by two quadrangular pyramids with rhombic faces.

It loses the brilliancy of its colours by the fire. M. Mongez considers it as infusible by the blow-pipe. Mr. Achard affirms that he fused it in a wind furnace.

One hundred parts afforded Bergmann forty alumine, twenty-five flint, twenty carbonate of lime, and thirteen iron. That of which Mr. Achard has given the analysis,



contained 41.33 alumine, 21.66 flrex, 20 carbonate of lime, 13.33 iron.

Hyacinths are found in Poland, in Bohemia, in Saxony, Velay, &c.

The hyacinth, rendered white by fire, is known by the name of Jargon. According to Mr. Lavoisier, the hyacinth of Puy in Velay becomes white in fire urged by vital air.

Its specific gravity, compared with that of water, is as 36,873 to 10,000.—See Briffon.

### DIVISION III.

Green Gems—the EMERALD, CHRYSOLITE, BERYL, &c.

1. The Peruvian emerald is of a green colour, electrical by friction, and crystallized in hexahedral prisms, truncated flat at each extremity.

The jaspers, or green schorles, which are called prase or mother emerald, have often been confounded with the emerald.

Crystals of emeralds are frequently found inserted in the gangues of quartz, and even of spar.

According to Mr. Sage, the more transparent emeralds are, the less their colour is changed in the fire. They become opaque, and of a greenish white. There are some which are reduced to enamel at their surface.

Mr. Darcet affirms, that in his experiments the emerald lost its transparency, and most of its colour, but that its form was not changed. In the experiments at Vienna in Austria, the emerald melted in twenty-four hours; and at Florence it was speedily fused by the burning mirror. Mr. De Saussure fused it by the blow-pipe into a compact grey glass; and Mr. Lavoisier, with a stream of vital air, fused it into an opaque milky bubble, whose internal part was greenish.

Its specific gravity, compared with that of water, is in the proportion of 27,755 to 10,000.

One hundred parts afforded Bergmann sixty alumine, twenty-four flrex, eight lime, six iron.

Achard obtained 60 alumine, 21.26 flrex, 8.33 lime, and 5 iron.

The emeralds which come from America are called occidental. Peru and the Brazils afford the most beautiful: they may be distinguished by the colour; that of Peru is of a satin colour or appearance; the colour of the Brazilian is less lively.

The emerald is the softest of gems, and may be scratched by the topaz, the sapphire, &c.

2. The chrysolite or peridot is of a green colour, slightly inclining to yellow.

Its form is that of an hexahedral pyramid with unequal sides, frequently striated, and terminating in two hexahedral pyramids.

Mr. Sage affirms that this stone suffers no alteration in the most violent heat, its colour not being so much as altered: and the same chemist pretends that Wallerius did not operate on a true chrysolite, because he affirms that it lost its colour. Messrs. Lavoisier and Erhmann fused it into a white, dirty, dull-coloured glass, by the assistance of vital air.

The specific gravity of the Brazilian chrysolite is in proportion to that of water as 26,923 to 10,000.—Brissou.

Masses of granulated chrysolite of various shades of green colour are found in the prismatic basaltes, and in several other volcanic products.

These chrysolites are common in the volcanos of our province. Mr. Sage received from Auvergne an hexagonal prism six inches in diameter, formed by the union of chrysolites of different colours.

3. The beryl, or aqua marina, is of a very bluish green.

The Saxon beryl, as well as that of Siberia, sent to Mr. Sage by Mr. Pallas, exhibits hexahedral, striated, truncated prisms, of a lamellated texture.

The pure beryl decrepitates in the fire, loses its transparency, and is fusible by the blow-pipe.

Its specific gravity, in proportion to water, is as 35.489 to 10,000, for the oriental aqua marina; and 27,227 to 10,000 for the occidental.—Brissou.

A blue aqua marina, in long, flattened, tetrahedral prisms, grooved longitudinally, and united sideways, is found among the granites of Spain, and on the declivity

of Saint Symphorien, near Lyon. This stone is very common at Baltimore in America.

#### DIVISION IV.

##### Blue Gems—SAPPHIRE.

The colour of the sapphire is a sky-blue. The sapphires of the brook d'Expailly have a green tinge, and change in the fire in the same manner as those of the Brazils; whereas the oriental sapphire is not changed in our ordinary furnaces. Mr. Erhmann caused the clear oriental sapphire, and of a perfect blue, to run into an opake white globule by fire excited by the stream of oxigene.

The experiments of Messrs. Achard, Sage, D'Arcet, Erhmann, Lavoisier, Geyx, Quist, &c. exhibit a variety of results in the analyses of gems by fire, which can be attributed only to the manner in which they applied it; and more especially to the very variable nature of the stones upon which they made their experiments.

The oriental sapphire, and that of Puy, have the form of two very long hexahedral pyramids joined and opposed base to base, without an intermediate prism. Mr. Sage saw a sapphire in a rhomboidal cube, or six-sided figure.

The sapphire analysed by Bergmann afforded him per quintal, 58 parts alumine, 35 silex, 5 lime, and 2 iron.

Mr. Achard obtained from his analysis 58.33 alumine, 33.33 silex, 6.66 lime, and 3.33 iron.

The specific gravity of the sapphire of Puy is in proportion to water as 40,769 to 10,000; that of the white oriental sapphire is as 39,911; and that of the Brazilian sapphire is as 31,307.

#### SPECIES II.

Silex, sometimes pure, but oftener mixed with a very small quantity of Alumine, Lime, and Iron.

This species essentially comprehends quartz and rock crystal.

The name of Quartz is given to the opake, or irregularly-figured vitrifiable stone; and that of Rock Crystal to the same stone crystallized. As the principles are

nearly the same, this circumstance naturally establishes a division of these stones into two classes.

# DIVISION I.

## Rock Crystal.

Rock crystal is a stone which exhibits *silice* in a state more nearly approaching to purity than in any other natural substance yet observed. Mr. Gerhard has even found specimens perfectly pure; but one hundred parts of crystal, strictly analysed by Bergmann, afforded him ninety-three parts *silice*, six alumine, and one lime.

The ordinary form of rock crystal is that of an hexahedral prism, terminated by pyramids of an equal number of sides. The varieties of the several crystals may be reduced to this geometrical form.—Consult Romé de Lisle.

Quartz crystallizes likewise in cubes. This form exists in various specimens in the cabinets of Germany; and Mr. Macquart brought a specimen with him to France.

The formation of this crystal appears to be owing to water, for we often find this fluid in the internal part of crystals; and they are evidently formed in the clefts and cavities of the primitive rocks, by the concurrence of this agent. But hitherto we have acquired very little knowledge respecting the circumstances of this operation.

Bergmann obtained rock crystals by dissolving *silice* in the fluoric acid, and suffering it to evaporate slowly. I left on the tables of my cabinet of mineralogy a receiver and a retort, in which I had made the acid of fluor; and when I had occasion, two years afterwards, to inspect this apparatus, I found the receiver almost entirely corroded, and its interior surface lined with a subtle powder, in which thousands of rock crystals might be discerned.

Mr. Achard informed the public that he had obtained rock crystals by causing water impregnated with carbonic acid to filtrate through clay. Mr. Magellan even presented these crystals to the Academy at Paris; but the experiment, though repeated with the greatest care by several chemists of the capital, was not attended with the same results.



Since that epocha, Mr. De Morveau, having inclosed rock crystals with a bar of iron in a bottle filled with gaseous water, perceived a vitreous point fixed to the iron, which he supposed to be a rock crystal formed by this operation; so that he considers iron as a necessary intermedium to enable the carbonic acid to dissolve quartz. This consequence of Mr. De Morveau appears to agree with many facts which have been collected concerning the formation of rock crystal. We see it formed in ochreous earths; and I possess ochres in my collection which possess many of these small two-pointed crystals.

It appears to me that it is not necessary to seek for a solvent for silica, in order to explain the formation of rock crystal. The simple division of this earth appears to me to be sufficient for the purpose; and I could bring numerous facts to support this assertion.—See the article Crystallization.

It is proved by the observations and experiments of Mr. Genissane, that a quartzose gurg is formed by simple transudation upon rocks of this nature; and the same naturalist has taken notice that, when the gurg is worn and deposited by water, rock-crystals are formed. The waters which work their way through the quartzose rocks of the mine of Chamillat, near Planché les Mines in Franche-comté, form quartzose stalactites to the roof of the works, and even upon wood. The extremities of these stalactites which have not yet assumed a solid consistence, are of a granulated and crystalline substance, easily crushed between the fingers.

In these cavities, called *craques* by the miners, a fluid gurg is often found, and still oftener crystals ready formed. I have seen at Saint Sauveur, in the work of La Boissière, near Bramebiaou, several incrustations of gurg on the sides of the gallery; and these spreading incrustations were terminated by well-formed crystals, wherever the wall overhung or deviated from the perpendicular. This gurg, when handled, and minutely examined, had no other appearance than that of a siliceous paste of considerable purity.

The same effects appear to take place with regard to rock crystals, as with the calcareous spars. They are formed whenever their principles, in a state of extreme

division and attenuation, are suspended by water, and deposited with all the circumstances which nature requires in order that crystallization may take place. I do not even think it necessary to recur to the property which water possesses of sensibly dissolving silica, to explain the formation of these crystals: and we shall refer the formation of quartzose stalactites, agates, &c. to the same cause.

Rock crystal is frequently coloured by iron, in which case it assumes peculiar shades, which have been denoted under different names. We shall place them here as simple varieties.

#### VARIETY I.

##### Red Crystal—FALSE RUBY.

It is frequently mixed with different shades. Its colour is destroyed by fire, according to Mr. D'Arcet. It is found in Barbary, in Silesia, in Bohemia, &c.

When it is of a dull red, it is called the Hyacinth of Compостella.

#### VARIETY II.

##### Yellow Crystal—BOHEMIAN TOPAZ.

It has sometimes a tinge inclining to yellow; its colour is often internal only. It is found in Velay, near Bristol in England, &c.

#### VARIETY III.

##### Brown Crystal—SMOKY TOPAZ.

This brown tinge varies from a light brown to a deep black. It is affirmed that they may be rendered clear by boiling them in tallow.—See *Journal de Physique*, t. vii. p. 360.

It is found in Switzerland, in Bohemia, in Dauphiny, &c.

#### VARIETY IV.

##### Green Crystal—FALSE EMERALD,

This is the most scarce and the most precious of coloured crystals. It is found in Saxony and Dauphiny.

#### VARIETY V.

##### Blue Crystal—WATER SAPPHIRE.

It does not appear to differ from the true sapphire, excepting in being less hard. I have seen a specimen

which had this colour. It is found in Bohemia, in Silesia, and at Puy in Valay, which has caused it to be called the Sapphire of Puy.

VARIETY VI.

Violet Crystal—the AMETHIST.

Its colour is more or less deep; and it assumes a considerable brilliancy by polishing. When the crystal is only half coloured, it is called *Prime d'Amethyste*. It loses its colour by a strong fire, according to Mr. D'Arcet. This crystal is found of sufficient magnitude to form columns of more than one foot in height, and several inches in diameter.

DIVISION II.

Quartz.

Those specimens of siliceous stone in which no regular form appears, and which we here comprehend under the name of Quartz, possess various degrees of transparency.

Its colour differs prodigiously; and it may be distinguished into varieties and shades perhaps more numerous than in rock crystal itself.

It seldom forms entire mountains, but almost always intersects, by veins more or less wide, the mountains of primitive schistus. At all events, I have made this observation in every mountain of this kind which I have examined.

The blocks of quartz, detached by waters, are rolled, rounded, and deposited in the form of large stones on the banks of rivers. The same stones, more attenuated, form the quartzose pebbles; and these, still more divided, produce sand.

This stone is very refractory. It is used as the basis of bricks employed in the construction of glass furnaces. For this purpose it is calcined to whiteness, and in that state thrown into water. By this means it may be easily reduced to powder, and disposed to form a combination with clay.

Quartz, well pounded, and used in the composition of bricks, does not equally resist the impression of fire, if the precaution of calcining it, and extinguishing it in water,

has not been taken. I have obtained a proof of this fact, by employing the same kind of quartz in both ways.

This sand forms an excellent mortar with good lime; and, when fused with alkalis, it produces a very beautiful glass.

### SPECIES III.

Silex, Alumine, Lime, and Iron, intimately mixed.

The state of fineness in the constituent principles, and their more or less intimate mixture or amalgamation, appear to us to establish two divisions among the stones of this species. We shall accordingly distinguish them into coarser flints and finer flints. The first form gun flints, petrosilex, &c.; the second comprehend agates, calcedonies, &c.

### DIVISION I.

#### The Coarser Flints.

In this place we shall arrange two stones which appear to differ only by a more or less evident degree of transparency. The filex, or flint properly so called, is semi-transparent, when very thin, as for example at its edges: the petrosilex has a more opaque colour.

1. Gun Flint.—The gun flint gives fire with steel: its colour is usually brown; and its surface very frequently exhibits a whiter colour than the middle, and less hard than the nucleus of the stone. This external part sticks to the tongue, and indicates a commencement of decomposition.

The abbé Bacheley has asserted that marine productions, such as polipiers, shells, &c. are capable of passing to the state of gun flint.—*Journal de Physique, Supplement, 1782, t. xxv.*

The specific gravity of gun-flint is from 2.65 to 2.7. This stone does not melt in the fire; but it becomes white and brittle by repeated calcinations.

The common brown filex afforded by analysis to Mr. Wiegleb, per quintal, eighty filex, eighteen alumine, and two iron.



2. *Petrofilex*.—The colour of *petrofilex* is a deep blue, or a yellowish grey. It is interspersed in veins through rocks; and from this circumstance it derives its name.

Its specific gravity is from 2.59 to 2.7.

It becomes white in the fire like gun flint; but it is more fusible, for it flows without addition. Soda does not totally dissolve it in the dry way; but the borate of soda, and the phosphates of urine, dissolve it without effervescence.

Mr. Kirwan obtained from a *petrofilex*, used in the manufacture of porcelain by Mr. Lauraguais, seventy-two parts *filex*, twenty-two *alumine*, and six *lime*, in the quintal.

## DIVISION II.

### The Finer Flints.

This division exhibits several stones, which, though distinguished by names and a different value, are nevertheless only varieties of each other. We shall content ourselves with enumerating the chief.

1. *Agate*.—This is a semi-transparent *filex* of a very fine body. Its texture is vitreous; and its hardness such that it resists the file, gives fire with the steel, and takes the most beautiful polish.

The *agate* when exposed to the fire, loses its colour, becomes opaque, and does not melt.

The varieties of *agates* are infinite. They are founded on the colour; and they are distinguished into clouded, punctuated, spotted, irised, herborized, mossy, &c. See Daubenton.—The name of *Onyx* is given to that kind of *agate* which is formed by concentric bands. Mr. Daubenton has proved that the *agate* which has received the name of mossy, is really coloured by small mossy vegetations.

The purest *agate* is white, transparent, and nebulous. Such is the oriental *agate*, which besides appears as if it had protuberances or knobs on its surfaces.

Its specific gravity is 2.64. I consider the *agates*, and the other flints concerning which we shall proceed to treat, as quartzose *stalactites*. The sides of *geodes* which are *agatized*, and the strata of those flints which are found in

places where infiltrations produce rock crystals, appear to me conclusive in favour of this doctrine. The agates have the same relation to quartz as the alabasters to calcareous stones, and the theory of their formation is the same. Mr. Dorthes has exhibited many proofs of this theory respecting the formation of these stones.

2. The Opal.—The semi-transparent agate of a milky whiteness, which exhibits a glittering, changeable, internal colour of a blue, red, and green tinge, is known by the name of Opal. That which comes from Hungary has a kind of greyish clay for its gangue. The most beautiful opal is the oriental opal; sometimes called the spangled opal, because its colours appear like equal spots distributed over its whole surface. These opals have received various names, according to the colours they reflect.

The chatoyant stones, or such as vary their colour according to the position of the light, and the eye of the observer, are varieties of the opal. Such are the girasol, the cat's eye, the fish's eye.

The reflected rays of the girasol are weak, blueish, and mixed with an orange yellow. This stone has been found in the lead mines of Chatelaudren in Brittany. The most obvious character of the girasol is, that it exhibits in its internal part a luminous point; and reflects the rays of light in whatever position it may be turned, when it is cut into a globe or hemisphere. The cat's eye has a point near the middle, from which proceed, in a circle, greenish traces of a very lively colour. The most beautiful stones of this kind are of a grey and mortdoré colour. They come from Egypt and Arabia.

The fish's eye does not differ from the cat's eye excepting in its colour, which is blueish: it is found at Java.

3. Calcedony.—The calcedony is a semi-transparent agate of a milky whiteness, differing from the foregoing in not possessing the chatoyant property, or changeableness of colour.

It has been found in the mines of Cornwall, in stalactites of singular elegance. These calcedonies are almost always covered with protuberances like the stalagmites.

The protuberances appear to be formed by the successive apposition of several strata or coatings.

In Monte Berico, in the territory of Vicenza, geodes of calcedony are found which inclose water. They are called Enhydria.

I possess, in the Mineralogical Cabinet of the province, calcedonies of Auvergne, which appear to be crystallized like rock-crystal. The crystals have all the fat and unctuous appearance of the same balls which are dispersed on the rock; but, when they are broke, it is seen that the appearance arose from a covering of calcedony over the crystal of quartz.

Mr. Bindheim analysed calcedony, and found, in the centenary, 83.3 silex, 11 lime, 1.6 alumine, and a small quantity of iron.—Schrift. Natur. For. Free. t. iii. p. 429.

Mr. Darcet did not succeed in fusing calcedony, but it lost its colour.

Calcedony has often a shade of blue, yellow, or red.

Mr. De Carozzy and Mr. Macquart observed in Poland the transformation of gypsum to the state of calcedony.—See the *Essai de Minéralogie* par M. Macquart, premier mémoire.

Cacholong. The white and opaque calcedony is known by the name of Cacholong. Its texture resembles that of quartz, and it becomes white in the fire. This stone is capable of a fine polish. It is found on the banks of a river named Cach, near the Kal mouks of Bucharia, in whose language the word *cholong* signifies stone.

An imaginary value has been given to a modification of the cacholong, which has the property of becoming transparent after having been plunged in water. This is called Hydrophanes, Lapis Mutabilis, Oculus Mundi. Mr. Dantz brought hydrophanes to Paris which became transparent when plunged in water.

Mr. Gerhard, on the 28th of August 1777, read to the Academy of Berlin Observations on the Hydrophanes. He found that this stone contained two-thirds of clay, and one third of silex. This celebrated naturalist affirms that the hydrophanes was known to Boyle, who saw one of them about the size of a pea sold in London for two hundred pounds sterling.

The hydrophanes is fusible in the fire. Soda dissolves it with effervescence; the borate of soda, and the phosphates of urine, without effervescence.

5. Carnelian. Sardonyx. The carnelian is a species of agate, nearly transparent. It is called Carneole when it has the colour of flesh. Its hardness varies prodigiously. Those which are white or yellowish are not sufficiently hard to give fire with the steel. When ignited it loses its colour, and becomes opaque. The most beautiful specimens resemble the garnet. Its specific gravity is from 2.6 to 2.7.

The sardonyx is a semi-transparent silex, of an orange colour, more or less deep. It is knobbed like the calcedony; and possesses the hardness and specific gravity of that stone. Its habitude in the fire resembles that of the agate. In the Royal Wardrobe of France there are vessels of sardonyx of an astonishing magnitude and beauty. The famous murrhine vases were of sardonyx. Sage, t. ii. p. 163.

#### SPECIES IV.

Silex, Alumine, and Iron.

Jasper is one of the hardest stones we are acquainted with. It is susceptible of the finest polish; and its colour varies prodigiously, which has occasioned it to receive the names of Sanguine Jasper, Green Jasper, Flowered Jasper, &c.

Mr. Wedgwood assured Mr. Kirwan that jasper hardens in the fire without melting; and Mr. Lavoisier could not obtain a perfect fusion by the assistance of oxygenous gas. The surface only becomes vitreous.

Mr. Gerhard asserts that some species are fusible; and Mr. Kirwan attributes this property to the mixture of lime and iron which produces the fusion.

Its excessive hardness has induced the savages of Canada to avail themselves of it in the fabrication of the heads of javelins.

Mr. Dorthes has found, among the worn stones of the Mediterranean shore, javelin-heads of porphyry, jasper, horn-stone, schorl, variolite, &c. probably fabricated by the ancient inhabitants, the Gauls.



These javelin-heads are commonly known by the name of Thunder-stones, and are distinguished by lithologists by the name of Ceraunites.

## SPECIES V.

Silex, Alumine, Lime with a small portion of Magnesia, and Iron.

This species comprehends all the schorles; and most of the volcanic products. As the tourmaline is evidently nothing more than a variety of the schorl, we shall place it here, though analysis has not discovered an atom of magnesia in it, and the nature of its principles confounds it with precious stones. Moreover by placing it between these and the schorls, it possesses a situation assigned to it as well by its natural characters as by its constituent principles.

I. The Tourmaline.--This stone possesses the transparency of the schorl. Its appearance and fracture are vitreous, its texture lamellated, its hardness so considerable as to cut glass. When heated to the two-hundredth degree of Fahrenheit, it becomes electrical; a stronger fire deprives it of this property. It is fusible by the blow-pipe, with ebullition: the pure tourmaline was melted into a black glass, in the experiments of Mr. Lavoisier.

Tourmalines have been found in the island of Ceylon, in Tyrol, and in Spain.

Its form is that of a nine-sided prism, terminated by two flat trihedral pyramids. Mr. De Joubert possesses one whose prism is seven inches and a half long, and eleven inches in circumference.

The prismatic tourmaline has no electric effect but according to the direction of its column; the sphere of activity of the Spanish tourmaline is more extensive than that of Tyrol.

The valuable researches of Bergmann upon this stone may be consulted in his dissertation concerning its analysis. Mr. Tofani has annexed a set of interesting notes to his translation of this work.

The results of Bergmann's analysis exhibit its component parts in the following proportion:

1. The tourmaline of Tyrol contains alumine forty-two, fîlex forty, lime twelve, iron six.

2. The tourmaline of Ceylon, alumine thirty-nine, fîlex thirty-seven, lime fifteen, iron nine.

3. The tourmaline of Brazil, alumine fifty, fîlex thirty-four, lime eleven, iron five.

The specific gravity of the tourmaline of Ceylon is 30,541, that of Spain and of Tyrol is 30,863, water being 10,000.—See Briffon.

II. Schorl. The distinct properties of schorl are, an appearance of semi vitrification, fusibility in a moderate fire, and hardness approaching to that of crystal.

There are few stones which exhibit a greater variety of form or colour.

They enter into the composition of porphyry, of serpentine, of granite, and are very frequently found with the magnesian stones.

We shall distinguish the schorls into crystallized and irregularly-shaped schorls.

A. All the varieties which depend upon colour may be reduced to four.

1. Black Schorl.—The black schorl is found chiefly in granites. It has almost always the form of prisms more or less perfect. The number of sides of these prisms is various; they are sometimes grooved; they sometimes terminate in trihedral obtuse pyramids, placed in contrary directions; in some places they are found several inches long, and the union of these prisms frequently forms groupes of several in diameter. Their black colour is more or less deep. When urged by fire, they become resolved into a black uniform glass of an imperfect fluidity like paste.

The analysis of the black prismatic schorls of Gevaudan afforded me, per quintal, fifty-two fîlex, thirty-seven alumine, five lime, three magnesia, and three iron.

2. Green Schorl.—This variety exhibits the same form, and the same modifications; but the most common of its crystallizations is that of a tetrahedral prism, terminating in short pyramids likewise tetrahedral.

3. Violet Schorl.—This variety was discovered in 1781 by Mr. Schreiber, below the grotto of Aunis; situated at the distance of one league from Bourg D'oisan in Dauphiny.

Mr. De la Peyrouse likewise found it at the Peak of Dretliz. in the Pyrenean Mountains.

This Schorl possesses a certain degree of transparency. It is crystallized in rhomboides; its texture is lamellated; two of the rhomboidal planes of each pyramid have their faces striated parallel to each other.

Schorl loses its colour in the fire, and one thirteenth of its weight; it becomes of a greyish white: and with a stronger degree of heat it swells up, subsides, and forms a black enamel.

Its specific gravity is 32,956, according to Briffon.

4. White Schorl.—This variety has been found in the mountains of Corsica, Dauphiny, and the Pyrenees. It is of an opaque white colour, and vitreous appearance; and is found in crystals on the surface of certain stones of the nature of the lapis ollaris. I have seen a layer of this schorl between amianthus and the lapis ollaris. It melts in the fire into a white enamel.

The analysis of this schorl from the Pyrenean Mountains afforded me, per quintal, fifty-five parts flex, twenty-two alumine, thirteen magnesia, and seven lime.

B. The schorl in connected masses nearly approaches the jasper in its external characters. It may be distinguished however by its fracture, which is of a dryer grain, and exhibits a disposition to crystallization. This stone serves as the basis to several porphyries. The variolite of Durance, a stone singular on account of the superstitions to which it has given rise, is a schorl in the mass, covered with grains of the same nature as the ground, but of a clearer green.

Mr. Derthes has observed variolites on the coast of our Mediterranean sea; and affirms that this stone in its decomposition undergoes changes of colour which succeed each other in the order of the solar spectrum.

III. Volcanic products.—The principal products of volcanoes are basalt, lava, and terra pozzolana. These substances are absolutely of the same nature; but they are principally distinguished by the name of Basalt when their form is regular. When they have no determinate figure, they are denominated Lavas; and when consider-



ably attenuated they are distinguished by the name of Terra Pozzolana.

Basaltes is distinguished into the prismatic basaltes with a number of sides, from three to seven; the basaltes in tables and the spherical basaltes.

Lava is distinguished into compact lava, porous lava, twisted lava, lava in tears, &c.

Several naturalists have classed the basaltes with the schorls, and some of them have assigned the same origin to both. It appears nevertheless to be generally agreed that basaltes is a product of fire.

It sometimes differs from schorls in its chemical analysis, and also in the circumstance of its not always affording magnesian earth.

The colour of basaltes is of a deep green, almost constantly covered or enveloped with a ferruginous crust less black than the internal part. The iron is in the state of ochre.

Its form is constantly prismatic, which is the natural effect of the contraction which it suffers in cooling.

Basaltes is converted by fire into a most beautiful black glass. This property, which is admitted by every chemist, induced me to fuse it, and blow it into bottles.

The attempt was perfectly successful at the glass-house of Mr. Gilley of Allais, and at that of Mr. Giral of Erepian. I still preserve the first vessels which were blown of this substance: they are of the most beautiful black, astonishingly light, but without transparency. Encouraged by this first success, I requested Mr. Castelveil, the proprietor of another glass-house, to undertake some experiments; and in consequence of various trials we succeeded in fabricating bottles of an olive green, in which the most extreme lightness, and a truly astonishing degree of solidity, were united. Pounded basaltes, soda, and sand, in nearly equal proportions, formed their composition. The properties of these bottles, as proved by my own experiments, as well as by those which Mr. Joly De Fleury, at that time comptroller-general, ordered to be made, render them of the greatest value in commerce; and Mr. Castelveil was unable to supply the numerous orders he received. This manufacture supported itself with success for two years: but at



the end of that time the superiority of the bottles ceased to be the same; the manufacturer received the reproaches of the consumer; this superb establishment gradually fell off, and was at length abandoned.

Since that period I have made several experiments in the large way, from which I have obtained results that may be of service to such as are desirous of following this manufacture.

1. The nature of the combustible used in glass-houses has a prodigious effect in modifying the results of experiments. The same basaltes which Mr. Castelveil considered as too refractory in his furnace heated by wood, was found of too fusible a nature by Mr. Giral, who was in the habit of using pit-coal in his glass works. The former manufacturer accordingly made his glass by adding soda to the lava, whilst the latter mixed it with a very refractory sand.

2. The same lava, fused without addition, may be blown in one glass-house, and not in another. This irregularity appeared to me at first to depend essentially on the skill of the workmen; but I have been since convinced that it is totally independent of that circumstance.

In a furnace which is strongly heated, the fused lava sometimes becomes fluid like water, and drops from the iron tube as soon as it is collected. The same lava, when fused in other furnaces, will preserve a sufficient degree of consistence to admit of being blown. I am myself well assured that the lava might be wrought in any glass-house whatever, provided the moment was seized in which the paste was neither too fluid nor too thick to be wrought; but these attentions are too delicate, and too minute, to be observed in works in the large way.

3. The hardest basaltes affords the most beautiful glass. When it is contaminated with foreign principles, such as the nodules of lime, the glass is brittle, and has not a sufficient connection of its parts. This circumstance, in my opinion, was the cause of the bad quality of the glass, which produced the failure in Mr. Castelveil's manufactory.

4. I have seen very hard basaltes interspersed with black infusible points, insomuch that these points became enveloped in the vitreous paste without any perceptible altera-

tion. The volcanic mountain of Escandorgue near Lodeve afforded me this variety of basaltes.

In the article *Verrerie* of the *Encyclopédie Méthodique*, may be seen the various results which we have obtained with Mr. Allut, in several experiments made in common in the royal glass works of Bosquet and elsewhere.

I shall conclude, from the observation which my experiments have hitherto afforded—

1. That lava may be used as a flux in glass-houses to diminish the consumption of soda. This is the single purpose I at that time proposed to myself, and I have clearly accomplished it. 1. By the results of experiments which have shewn that refractory sand becomes fused in the glass furnace by a mixture of lava. 2. By the effects obtained in all the works in the large way, in which the addition of lava permitted a diminution in the proportion of soda.

2. It is very difficult to establish a rigorous process, applicable to all circumstances, by which lava may be wrought without addition. My bottles into which the lava entered as a component part, were scarcely known, before it was published that they were formed of lava without addition; nothing more being said to be required than to fuse the lava in order to form bottles. This strange report affected me very little in the principle; because I had neither spoken, written nor printed any thing which was capable of giving authority to such an error: and I was content to reply to all persons who demanded information, by informing them that experience had taught me that an addition of lava diminished the proportion of soda in the composition of glass, and that this new principle rendered the bottles lighter and stronger.

3. That the only advantage which can be derived from fusing lava without addition, is to pour it out into moulds, to form paving stones, chimney jams, &c. The facility with which it is fused by the assistance of pit-coal, would render these works of small expence; and it might easily be decorated by incrusting it with metallic colours.

4. That the difference in the nature of volcanic products produces such a variety in the results of their fusion, that I consider it as impossible to assign a constant and invariable process, by which the same result may infallibly be

obtained. This circumstance renders it necessary to make preliminary trials in all cases wherein it is intended to use basalt in the fabrication of bottles.

The basalt has been considered as similar to a stone known by the name of Trapp: it resembles it in several essential properties; the colour, form, weight, and the nature of the component parts of each, appear to authorize us in confounding them together, as Bergmann has proved by the fine comparison he has made of these two stones, in his analysis of the volcanic products of Iceland. But this same chemist has shewn that they differ in several other points of view.

The trapp exhibits no character which can give ground to suspect that its origin is volcanic; it is found in Sweden, in the primitive mountains, and upon strata of granite and schistus, and sometimes even upon banks of calcareous stone.

The trapp of the mountains of Westrogothland is usually in the form of square irregular cubes; and it is indebted for its denomination to this resemblance to the steps of a stair case. It likewise exhibits the form of a triangular prism, though seldom; and sometimes it resembles immense columns.

The trapp afforded Bergmann the same principles, and nearly in the same proportion, as the basalt. The difference is scarcely the hundredth part; and this variation is frequently found in pieces of the same basalt.

#### SPECIES VI.

Silex, Lime, Magnesia, Iron, Copper, and the Fluoric Acid.

This combination forms the chrysoprase. Its colour is a semi-transparent apple green, and it is harder than the fusible spars and quartz of the same colour.

The fire deprives it of its green colour, renders it white and opaque, and forms by the assistance of vital air a compact and milky globule.—See Erhmann.

Mr. Achard obtained, in the quintal of this stone, 95 parts silex, 1.7 lime, 1.2 magnesia, 0.6 copper.



## SPECIES VII.

Silex, the blue Fluete of Lime, with the Sulphate of Lime and Iron.

This singular combination forms the *Lapis Lazuli*, or *Azure Stone*.

Its colour is of a beautiful opaque blue, which it preserves in a strong heat, and does not suffer any alteration in this respect by the contact of air.

The powder of this stone makes a slight effervescence with acids; but after calcination it forms a jelly with acids, without exhibiting any previous effervescence.

The powder of this stone forms the valuable colour known by the name of *Ultramarine*. The price of this colour is proportioned to its intensity; and its value is accordingly least when it is mixed with pyrites, because these bodies diminish the vivacity of its colour.

This stone affords water by calcination, and when distilled with the muriate of ammoniac, it forms martial flowers; which proves, according to Mr. Sage, that its colour is owing to iron.

The azure stone is fused by a strong heat into a whitish glass; and by the assistance of oxigene it forms a white transparent globule inclining to green, without internal bubbles, and not obedient to the magnet.

The specific gravity of the lapis lazuli of Siberia is 29,454.—See Briffon.

Plates of the lapis lazuli may be seen upon almost all richly decorated altars; it is likewise made into toys.

Margraff obtained from this stone calcareous earth, gypsum, iron, and silex. Mr. Rinmann has discovered that it contains the fluoric acid.

## SPECIES VIII.

Silex, Alumine, Barytes, and Magnesia.

This stone is known by the names of *Feld Spar*, *Rhombohedral Quartz*, *Spathum scintillans*, *Petuntze*.

It very frequently forms one of the principles of granite, and the crystals, which are found separate, arise from the decomposition of this primitive rock.

The texture of feld spar is close, lamellated, and it is less hard than quartz.



It fuses without addition into a whitish glass. I have nevertheless observed a very great variety in the feld spars, with regard to their habitude in the fire. That of Avenne, which is in the form of whitish crystals mixed with quartz, afforded me a transparent glass of extreme hardness by the simple addition of one-third of lime: whereas that of Esperon, treated in the same manner, did not exhibit the smallest sign of fusion.

The specific gravity of white feld spar is 25,946.—See Briffon.

Feld spar exhibits several varieties in its form and colour.

Most of the pieces of feld spar inclosed in granite have a rhomboidal form; and when this primitive rock becomes decomposed, the crystals of feld spar are detached, and remain confounded with the rubbish. The granites of our province, almost all of them, contain these crystals, some of which are an inch and a half in diameter.

Feld spar has been found crystallized in tetrahedral prisms, terminating in pyramids with four sides.

I possess some specimens of feld spar of Auvergne, whose tetrahedral prisms are flattened and terminated by a dihedral summit.

The principal shades of colour in feld spar are white, rose-colour, and chatoyant, or of changeable colours.

The white transparent feld spar is very rare; there is a piece in the Royal Cabinet of the mineral School, which comes from Mount St. Gothar.

One hundred parts of white feld spar contain about sixty-seven silica, fourteen alumina, eleven barytes, and eight magnesia.

The rose-coloured feld spar is not very scarce. Our mountains exhibit much of it. It abounds with iron, which is in the state of ochre. Some experiments have shewn me that this variety is more fusible than the others. My analyses have even exhibited a larger portion of magnesia; and its consistence appears to me to be less firm than that of other specimens.

Feld spar is composed of rhomboidal laminae, which give it the property of exhibiting various colours, in a greater or less degree. Large pieces of feld spar have been found on the northern coast of Labrador, worn down by the waters

into a round form, of a blueish grey colour, and exhibiting the most agreeable change of colours, according to the variation of position. The colours are a beautiful celestial blue, shaded with green. This stone is known by the name of Labrador Stone. Granites are frequently found in which the feld spar exhibits its changeable colours without being wrought.

## CLASS III.

Concerning the Mixtures of Stones among each other. Stony Mixtures. Rocks.

The mixture of the primitive earths with each other form the stones we have hitherto treated of; and these stones, united and connected together, or as it were joined by a cement, constitute the numerous class of pebbles or stones, concerning which we shall proceed to treat. It is evidently seen that the mixture of various stones has been produced, either by revolutions which have reversed and confounded the whole surface of countries, or by the action of waters, which have successively formed the strata of rounded flints spread over the surface of the globe, and have afterwards deposited in their interstices that earthy matter which has connected them together. These mixtures have afterwards acquired a degree of hardness; and at length appeared to form one single substance.

We shall establish our genera upon the presence of such stones as predominate; and the species will be deduced from the variety of stones mixed with that which determines the genus.

## GENUS I.

Rocks formed by the mixture of Calcareous Stones with other Species.

Though the basis of calcareous stones enters into the composition of the greater part of lithologic substances, we find few rocks which can be ranged in this class.

## SPECIES I.

Carbonate of Lime, and Sulphate of Barytes.

Mr. Kirwan observed compound stones in Derbyshire, formed of chalk intermixed with nodules of ponderous spar.

SPECIES II.

Carbonate of Lime and Mica.

The green marble or Cipolin of Autun is of this kind. It is composed of eighty-three parts carbonate of lime, twelve green mica, and one iron.—*Journal de Physique*, t. xii. page 55. Calcareous stones are found in Italy, which exhibit brilliant specks of mica, and are known by the name of Masigno.

SPECIES III.

Mixtures of Calcareous and Magnesian Stones.

Sulphate of lime, fluat of lime, and carbonate of lime are found mixed with steatites, serpentine, talc, amianthus, and asbestos. Such is, for example, the white marble interspersed with spots of steatites, and described by Cronstadt.

SPECIES IV.

Calcareous Stones, and Fragments of Quartz.

Quartz is sometimes found in calcareous cement. Sweden and Siberia exhibit several marbles which give fire with the steel. The calcareous grit, so common in the southern part of our kingdom, is of this species. The sand is composed of fragments of quartzose flints, rounded and connected by a calcareous gluten or cement. By digestion of grit-stone in an acid, the calcareous cement becomes dissolved, and the proportion which the sand bears to the whole may then be easily determined.

This grit-stone is seldom hard enough to be used in building, or in paving.

At Nemours, and at Fontainebleau, this stone has been found crystallized in perfect rhomboides: the cabinets of naturalists are enriched with superb samples of this kind.

Lime-stone has likewise been found serving as a cement for feld spar, schorl, &c. ; but this is somewhat rare.

Mr. De Saussure has described a stone whose elements are quartz and spar.

Our shores afford pebbles of hard marble of a light-grey colour, interspersed with feld spar and quartz.—See Dorthes,



GENUS II.

Compound Stones formed by the Mixture of Barytic Stones with other Stones.

As ponderous spar is of considerable scarcity, and is almost always found alone, this genus will not be numerous.

SPECIES I.

Ponderous Spar mixed with a small quantity of Calcareous Spar.

The dioceses of Alais and of Uzes afforded me this species; and I have myself observed in the latter rhomboids of calcareous spar, so well mixed with the laminæ of ponderous spar, that it is impossible to separate them without destroying the stone. It was among the veins of ponderous spar which are found on the road from Portes to Alais, that I saw this mixture.

SPECIES II.

Ponderous Spar and Serpentine.

Mr. Kirwan describes a species of serpentine with spots of barytes.

SPECIES III.

Ponderous Spar and Fluor Spar.

The ponderous spar of Auvergne is mixed with fluor spar: I have many specimens of this.

SPECIES IV.

Ponderous Spar and Indurated Clay.

This is the Kros-stein of the Germans. The clay which forms the ground is grey, and includes a ponderous spar of a white colour, which is disposed in this clay in the form of veins, that might be taken at first sight for vermiculites, or, in general, for the remains of some organized substances. This stone is found at Bochnia in Poland.

SPECIES V.

Ponderous Spar and Quartz.

I have in my collection several specimens, in which the ponderous spar is disposed in stars upon a matrix of the nature of flint.



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Gen: 3

SPECIES VI.

Ponderous Spar and Lava.

The extinct volcanos of the diocese of Beziers have afforded me lavas, partly decomposed, whose surface exhibits radii of ponderous spar, which, at first sight, I took to be zeolite.

GENUS III.

Rocks or Stones formed by the Mixture of Magnesian Stones with other Kinds.

SPECIES I.

Magnesian Stones mixed together.

The same rock often exhibits the various known magnesian stones in contact with each other. Thus we see the asbestos placed beside the amianthus, the serpentine in contact with the asbestos, the steatites in contact with talc.

SPECIES II.

Magnesian Stones and Calcareous Stones.

The serpentine has been found spotted with calcareous spar, and gypsum.

SPECIES III.

Magnesian Stones and Aluminous Stones.

Steatites is frequently mixed with clay. Its fibres are found bedded in an argillaceous substance. Steatites and serpentine are sometimes mixed with schistus.

SPECIES IV.

Magnesian Stones and Siliceous Stones.

Serpentine is found mixed with veins of quartz, feld spar, schorl, &c.

Asbestos and amianthus are often confounded, and sometimes incorporated in quartz and rock-crystals.

Mr. De Saussure has described a compound stone, of which the quartz is white, and the steatites green.

At Sterzing in Tyrol, is found a rock formed by schorl and serpentine.

In the county of Mansfield in Saxony, a rock has been discovered, composed of jasper and asbestos.

GENUS IV.

Rocks or Stones formed by the Mixture of Aluminous Stones with other Species.

## SPECIES I.

Schistus and Mica.

This mixture forms several primitive mountains. The mica is sometimes in plates of a certain thickness, but most commonly in small fragments; and the stone assumes a brilliant argentine appearance, which renders these stones agreeable to the sight. In this last case, the stone is nearly white, sonorous, and splits into leaves; whereas it is blackish, and less hard, when the mica is dispersed through it in large grains.

These kinds of micaceous schisti do not become spontaneously decomposed. They differ essentially from the pyritous schistus, whose formation appears to be posterior to that of the present species.

This micaceous schistus is a primitive stone. It does not include minerals, or at least very rarely; and it is not spontaneously decomposed.

## SPECIES II.

Schistus and Garnet.

The schistus frequently contains garnets, which rise in protuberances in its texture, and separate its strata from each other. The garnet is crystallized, and one would be disposed to affirm that this stone had increased, and almost vegetated, in the other, which serves as its covering. It is probable that the garnet has been enveloped by this paste of schistus; or that it was formed while the stone was still almost in the fluid state.

I found this schistus filled with garnets in the bed of the river Bramabiau, in the diocese of Alais.

## SPECIES III.

Schistus, Mica, and Quartz mixed in small fragments.

The Germans call this compound stone by the name of Gneiss. It deserves to be included among the quartzose and siliceous stones; but as it nearly approaches the primitive schisti we have just treated of, we shall follow the natural method in classing it here.

The texture of this stone varies greatly. It sometimes forms a rock in which neither ground nor fibres can be distinguished; in other specimens it appears to be divided into

filaments twisted in a thousand manners, and it frequently exhibits a lamellated hard texture.

It is found in large masses of a greyish green colour, with its surface shining, and polished like the slate; and it appears to be merely a fine-grained granite, the minuteness of whose parts has suffered them to take the foliated form of the schistus.

Mr. Weigleb has analysed that of Friburg.

#### SPECIES IV.

*Schistus and Schorl.*

The mixture of these two stones is common enough. The schorl is sometimes dispersed in very minute filaments, which give a blackish tinge to the mass. Its form is often prismatic; in which case the fibres of the schistus, and the long crystals of the schorl, form the prism by their reunion.

A schistus has been found in the Pyrenean mountains, in which the schorl is spread from space to space in the form of oblong bodies, and equally dispersed over the whole mass.

#### SPECIES V.

*Clay and Quartz.*

This constitutes the argillaceous grit-stone, or the stone in which fragments of quartz are united together by an argillaceous gluten.

Several varieties of grit-stone may be distinguished. It is often found in irregular, coarse, and compact masses, which are made into mill-stones, or used for paving, &c.

The magnitude of the fragments of quartz renders the surface more or less rugged; and it is this which renders it proper for certain operations of trituration.

When its grain is finer, it is made into grind-stones. It is by virtue of their quartzous principles that grind-stones emit such numerous sparks, when struck with the steel, or when they are moved with rapidity against any tool of that metal.

Argillaceous grit-stone is sometimes of a scaly texture: the *Cos Turcica* of Wallerius, and the stone used for sharpening scythes, are of this kind.

Fine grit-stone, composed of impalpable particles, is known by the name of Tripoli, from the part of Africa

whence it first came. It is now found in Rouergue, in Brittany, Germany, and elsewhere.

The porous grit-stone called Filtering-stone, on account of its use, is of the same nature.

Quartz is sometimes mixed with mica. Our province contains it in various places.

The mica is likewise found mixed,

1. With feld spar, according to Ferber and Kirwan.
2. With schorl, at Mont hykie in Dalecarlia in Sweden, and at Sterzing in Tyrol.

3. With garnets, at Paternion in Carinthia, and at the Carpathian mountains in Hungary.

4. With garnet and schorl, at Greyner.—See Muller.

5. With quartz, feld spar, and schorl. This composition forms one of the most common granites.

The mixture of these stones, varied in the proportion of their principles or elements, forms the numerous variety of granites; and several colours likewise modify them exceedingly.

#### GENUS V.

Compound Stones formed by the Mixture and Re-union of Quartzose Stones with each other.

#### SPECIES I.

Quartz and Schorl.

The quartz is, in general, white in this stone, and the schorl of various colours. Some of the paving-stones of London are of this sort, according to Kirwan. The schorl is likewise found in crystals within the quartz.

#### SPECIES II.

Quartz and Feld Spar.

A stone of this nature was brought me from the neighbourhood of Avenes. The mountain from which the specimen was detached, contains about one-third of quartz. The rest of the rock consists of rhomboidal feld spar, of no great firmness of texture, and constantly exhibiting the rhombus in its fracture.

I possess a very fine specimen of a similar rock, which was sent me from Fahlun in Dalecarlia.



SPECIES III.

Girt-stone and Garnet.

I have received from the mines of Tallard, near Gap in Dauphiny, girt-stones with garnets of one or two lines in diameter interspersed. These garnets are dispersed through the whole mass, at the distance of three or four lines from each other.

SPECIES IV.

Quartz, Feld Spar, and Schorl.

This mixture is common, and forms great part of the granites on our globe.

The proportion of the elements of this rock vary greatly, but the forms of the stones which compose it are not less variable. The schorl is frequently crystallized in prisms; the feld spar almost always exhibits rhomboidal laminæ, on breaking the stone; the quartz very seldom exhibits determinate figures, but it has nevertheless been found in superb crystals at Alençon and elsewhere.

The colour of these stones, likewise, exhibits an infinity of shades. The schorl is usually black; but it is sometimes found green, and even white, as in some granites brought from Spain. The feld spar is commonly of an ashen grey; but it has been observed of a flesh-colour, of a milk-white, of a dull red, &c. The most common appearance of the quartz is, that of a fat and vitreous substance. It is sometimes black.

SPECIES V.

Fragments of Quartz united by a Siliceous Cement.

We may here class the quartzose plum-pudding stones. The cement which unites these pebbles of quartz, which are commonly rounded, is the paste of petro-felix. Some of these pudding-stones are so compact, and their fracture is so uniform, that they are capable of the most beautiful polish, and produce a very happy effect by the variety of colour of the several flints connected by the same gluten.

SPECIES VI.

Jasper and Feld Spar.

This rock is known by the name of Porphyry. The jasper composes the ground, and the feld spar is interspersed in small needles, or in flat parallelopipedons.

The colour of porphyry varies prodigiously. The feld spar, which enters into its composition, is either white, or yellowish, or red; but the name of the porphyry is always dependent on the colour of the jasper. The jasper is sometimes green and sometimes black, and in some instances red; which establishes a great number of varieties.

As this stone is susceptible of the most beautiful polish, it has been employed as an ornament; and our temples, as well as private houses, are decorated with it.

Mr. Ferber found in Tryol porphyry in prismatic columns, resembling that of basalt; a circumstance which affords a further degree of probability to the opinion of such as have considered porphyry to be a volcanic production.

Porphyry is found in Egypt, in Italy, in Germany, in Sweden, in France, &c. Mr. Dorthes has brought, from various mountains in Auvergne, specimens of porphyric basalt in tables and in masses, containing crystals of feld spar, well formed, and little altered.

He observed that the rocks of Chevenon, an ancient convent of Gramontin, at the distance of one league from Artonne in Auvergne, were very beautiful porphyry. Mr. Guettard found it likewise in the forest of Esterelle in Provence.

Mr. Dorthes has described more than twenty varieties of porphyry thrown up in pebbles by the Mediterranean upon our coasts, whither they are brought by the Rhone. In many of these are found transparent quartz with the prismatic form, and crystallized feld spar.

Porphyry fuses into a black globule, marked with white points.

The specific gravity of red porphyry is 27,651, and that of green 26,760.—Briffon.

Porphyry sometimes contains schorl. Wallerius has described it “*Porphir rubens, cum spatho scintillante albo, et basalto nigro.*”

#### SPECIES VII.

##### Jasper and Garnet.

This stone has been discovered in Iceland: the ground is a green jasper, which includes ferruginous garnets crystallized, and of a red colour.

## SPECIES VIII.

Jasper and Calcedony.

The Mountain of Giants, in Bohemia, affords this stone. It has likewise been found in the Carpathian mountains, near Kaskau in Hungary. A stone has likewise been observed at Oberstein, in the Palatinate, composed of agate and jasper.

## SPECIES IX.

Jasper and Quartz.

This compound stone, called *Saxum Sibericum* by Linnaeus, has been found in Siberia, and also near Stutgard in the Duchy of Wirtemberg.

## SPECIES X.

Jasper, Quartz, and Feld Spar.

This stone is found in the environs of Geneva. Its ground is a jasper, or rather a petro-felix, black, opaque, and very hard. This matrix is interspersed with small rectangular crystals of white feld spar, and rounded grains of transparent quartz. Mr. De Saussure, who has described this species, places it among the porphyries.

## SPECIES XI.

Schorl, Garnet, and Tourmaline.

Mr. Muller has discovered in Schneeberg, a mountain of the territory of Sterzing in Tyrol, a rock of this kind, containing large crystals of tourmaline, which include small crystallized garnets, transparent, and of a red colour.

Mr. Ferber affirms that he found between Faistritz and Carnowitz in Stiria, detached pieces of green schorl, which inclose large red garnets: he adds, that this schorl is sometimes scaly, and of a micaceous texture.

Mr. De Saussure has found in the environs of Geneva, stones worn round by water, which were composed of schorl in the mass, and garnet.

The Mediterranean Sea throws up on our coast many varieties of rounded pebbles of porphyry, which have schorl for their basis.

## GENUS VI.

Super-compound Stones, or such as result from the Mixture and Re-union of several different Genera.

## SPECIES I.

Petroflex, Alumine, and Calcareous Spar.

This stone is found at Schneeberg in Saxony.

## SPECIES II.

Clay, Steatites, and Calcareous Spar.

This species, as well as the two following, are comprised under the name of Saxa Glandulosa. The steatites, the spar, and the other substances are dispersed in the matter which forms the ground of this rock.

## SPECIES III.

Clay, Zeolite, Schorl, and Calcareous Spar.

## SPECIES IV.

Clay, Serpentine, and Calcareous Spar.

## SPECIES V.

Serpentine, Mica, and Calcareous Spar.

Mr. Ferber has described this last species under the name of Polzevera; a denomination suggested to him by the place where it is found. See his Letters on Italy.

## SPECIES VI.

Serpentine, Schorl, and Calcareous Stone.

This stone furrounds the veins of the mine of St. Simon and Jude, at Dognasta, in the Bannat of Temesward: it is likewise found in copper mines of Saska; and at Hofer-schlag, near Schemniz, in Lower Hungary.

## SPECIES VII.

Steatites, Mica, and Garnets.

This stone is found at Handol in Jempterland, towards the north of Sweden.—Born. Ind. Foss. par. ii.

## SPECIES VIII.

Steatites, Mica, and Schorl.

This stone was found at Salbury in Westmanland, a province of Sweden.—Born. Ind. Foss. par. ii.



SPECIES IX.

Garnets, Quartz, Mica, and Serpentine.

This contains a small quantity of pyrites. It is found at Pusterthal in Tyrol.—See Bruckman.

SPECIES X.

Feld Spar, Quartz, Mica, Steatites.

Several granites are formed by a mixture of this nature. Such are found at Sunneskog in Sweden, and at Guten Hoffnangsbau near Altwoschitz in Bohemia: it is the *granites steatite mixtus* of Born.

SPECIES XI.

Quartz, Mica, and Clay.

This rock is the matrix of the ore of tin at Platte, and at Gottesgab in Bohemia.

SPECIES XII.

Quartz, Clay, and Steatites.

This is found at Mount St. Godard in Switzerland.

Concerning the Diamond.

The Diamond forms an appendix to the history of stones. Its combustibility is a character which prevents its being assimilated to any known species.

The diamond was long considered as the hardest and most ponderous of stones, as well as the only one which did not cause a double refraction; but subsequent observations have destroyed these early notions. The adamantine spar appears to equal it in hardness; the oriental ruby, and the jargon of Ceylon, are more ponderous; and the oriental precious stones exhibit one refraction only, as does likewise the phosphoric spar.

This precious stone is found on the coast of Coromandel, and principally in the kingdoms of Golconda and Visapour. The earth which serves as its gangue is red, ochreous, and soils the fingers.

The general process of exploring the diamond mines or earths, consists in mixing the earth with water, after which the fluid is poured off, and the sand which remains at the

bottom is dried by the strong heat of the sun.—See the Memoirs of the Comte Marechal.

Other naturalists inform us that, when the earths have been washed, the residue is left to dry, and is sifted in baskets made for the purpose. The workmen afterwards seek for the diamonds with their hands.

Diamonds in their native state are covered with two crusts; the one earthy, and the other sparry.—Romé de Lisle.

When lapidaries undertake to work them, they are obliged to find the grain of the stone, in order to split or cleave the diamond. If the fracture be not uniform, they call the stone a *diamond of nature*. The hardness of the diamond is such, that it resists the most highly polished steel; which circumstance renders it necessary to attack it by diamond powder.

The manner or form in which diamonds are cut, distinguishes them into rose diamonds, and brilliants, or brilliant diamonds. The brilliant diamond is cut into facets on both sides. The variety of forms given to these facets, and their different inclinations with respect to each other, multiply the refractions, and contribute to afford those reflections, and streams of pure and vivid light, which characterize the diamond.

The diamond is divided into two kinds; the oriental diamond, and the Brazilian diamond.

The oriental diamond crystallizes in octahedrons, and exhibits all the varieties of this primitive form.

The Brazilian diamond crystallizes in dodecahedrons. It is neither so hard, so heavy, so perfect, nor so valuable, as the oriental diamond.

The colourless diamond has a specific gravity which is in proportion to that of water as 35,212 to 10,000. Mr. Briffon has derived this specific gravity from an experiment on the *Pitt* diamond of the French crown. A cubic foot of this diamond would weigh two hundred and forty-six livres, seven ounces, five gros, sixty-nine grains.

The diamond is sometimes coloured green, violet, black, &c. The green are the most esteemed, because they are the most scarce. The weight of coloured diamonds is more considerable than that of the white diamond; because

it is augmented by the weight of the colouring principle, which is of a metallic nature.

The brilliancy, hardness, and scarcity of the diamond have preserved it in the most extravagant degree of estimation. A diamond is said to be of a fine water when it presents no defect or spot; and the price is proportioned to its purity.

When a diamond is without fault, its value is estimated according to its weight; which is determined or divided into carats, each carat being equivalent to about four grains.

The most beautiful diamonds hitherto known are—1. The two in the crown of the king of France; one of which is the Grand Sancy, weighing one hundred and six carats; and the other the Pitt, which weighs seven gros, twenty-five grains and one sixteenth. It is fourteen lines long, thirteen and a half broad, and nine and one-third thick. 2. The diamond which at present belongs to the Czarina weighs seven hundred and seventy-nine carats. The Empress purchased it in 1772 for twelve tons of gold (100,000 florins), and granted a pension of four thousand roubles to the seller. It is pretended that this fine diamond was one of those which ornamented the eyes of the famous statue Scheringham, which has eight eyes and four heads; and that it was carried off by a French deserter who had procured himself to be appointed as a guard to the temple of Brama. This diamond was at first sold for fifty thousand livres, afterwards for about four hundred thousand livres, and was at length purchased by the Empress of Russia.

The combustibility of the diamond is a phenomenon sufficiently interesting to induce us to give a faithful extract of the principal experiments which have served to advance our knowledge upon this subject.

Boyle observed, long since, that the diamond, exposed to a violent fire, emitted acrid vapours.

The emperor Francis the First caused crucibles to be exposed to a reverberatory fire for twenty-four hours, into which vessels the value of six thousand florins in diamonds and rubies were put. The diamonds disappeared, but the rubies were not altered. These experiments were repeated

with great expence; and it was ascertained that the diamond lost its polish, scaled off, and was dissipated.

The Great Duke of Tuscany, in 1694, caused experiments to be made by Mr. Averoni and Targioni, by the mirror of Tschirnhausen, and it was found that the diamonds disappeared in a few minutes.

In 1772, these experiments were resumed by the skilful chemists of Paris—Darcet, the Comte de Laraguais, Cadet, Lavoisier, Mitouard, Macquer, &c. The details of the interesting experiments made on this subject may be seen in the volumes of the Academy of Sciences, and the *Journaux de Physique*, of that year. We shall simply relate the results.

1. Messrs. Darcet and the Comte de Laraguais proved that the diamond is volatilized in balls of porcelain.

2. Mr. Macquer took notice that the diamond dilated and swelled up; and that a blue flame was observable on its surface during the combustion.

3. Messrs. Lavoisier and Cadet proved, that the combustion of diamonds in closed vessels ceased as soon as the oxigene was destroyed; and that the diamond did not burn but in proportion to the oxigene present, like all other combustible substances. The jewellers, who expose their diamonds to very violent fires to render them colourless, are careful to wrap them up in such a manner as to secure them from the contact of air.

Mr. De Sauffure burned a diamond by the blow-pipe: Mr. Lavoisier has proved that, when it is exposed to the burning glass, a dust arises which precipitates lime-water.

The diamond is therefore a combustible substance, which burns in the same manner as other bodies. This strict and accurate consequence is deduced from all the experiments which can be imagined to acquire a perfect demonstration.

Within a few years chemists have discovered a very singular stone, to which the name of Adamantine Spar has been given by Bergmann.

It is black, and so hard that its powder may be used to cut the diamond; from which circumstance it has obtained its name.



It crystallizes in hexahedral or six-sided prisms, two of which are large, and four small.

Its specific gravity is 38,732 with respect to water, which is assumed at 10,000. See Briffon.—The cubic foot weighs two hundred and seventy-one livres, one ounce, seven gros, sixty-three grains.

The most violent fire produces only a slight softening of this spar, according to the experiments of Mr. Lavoisier.

The analysis made by Mr. Klaproth of this stone, has exhibited a peculiar earth, which is suspected to be likewise one of the principles of precious stones, &c,

## GENERAL VIEWS

### RESPECTING

*The Decompositions and Changes to which the Stony Part of our Globe has been subjected.*

**I**F it were permitted to man to follow, during several ages, the various changes which are produced on the surface of our globe by the numerous agents that alter it, we should at this time have been in possession of the most valuable information respecting these great phenomena; but thrown, as we are, almost by accident, upon a small point of this vast theatre of observation, we fix our attention for a moment upon operations which have employed the works of nature for ages; and we are unable either to perceive or to foretel the results, because several ages are scarcely sufficient to render the effects or changes perceptible. Nature never ceases to exist: her activity has been coeval with the existence of matter; her operations are not circumscribed within limited times; she disposes of whole ages in the arrangement of her combinations; while

man can command no more than a few instants, and himself disappears at the moment wherein he has proceeded so far as to connect a few facts together. Hence, no doubt, it arises, that nature is incomprehensible in some of her operations, and inimitable in all those which require a long series of time.

It must be allowed that those men who, by the mere efforts of their imagination, have endeavoured to form ideas respecting the construction, and the great phenomena of this globe, have numerous titles to our indulgence. In their proceedings we behold the efforts of genius, tormented with the desire of acquiring knowledge, and irritated at the prospect of the scanty means which nature has put in its power: and when these naturalists, such as Mr. De Buffon, have possessed the power of embellishing their hypotheses with every ornament which imagination and eloquence can furnish, either as instruments of illusion or entertainment, we ought to consider ourselves indebted to them.

For our part, we shall confine ourselves to exhibit a few ideas respecting the successive decompositions of our planet, and shall endeavour to avoid every departure from observation and matter of fact.

The slightest observation shews us that living beings are kept up and perpetuated only by successive decompositions and combinations. A slight view of the mineral kingdom exhibits the same changes; and our globe, in all its productions, presents continual modifications, and a circle of activity, which might appear incompatible with the apparent inertia of lithologic products.

In order to arrange our ideas with greater regularity, we may consider this globe in two different states. We will first examine the primitive rock which forms the nodule or central part. This appears to contain no germ of life, includes no remains or part of any living being, and from every circumstance appears to have been of primitive formation, anterior to the creation of animated or vegetating bodies. We shall pursue the various changes which are daily produced by the destructive action of such agents as alter or modify this substance.

We shall then proceed to examine what stones have been successively placed upon this, and what are the

decompositions to which these secondary rocks have been subjected.

1. The observations of naturalists all unite to prove, that the central part of the globe consists of the stone known by the name of Granite. The profound excavations which the art of man, or currents of water, have made in the surface of our planet, have all uncovered this rock, and have been incapable of penetrating lower: we may therefore consider this substance as the nucleus of the globe; and upon this substance it is that all matters of posterior formation rest.

Granite exhibits many varieties in its form, composition, and disposition: but it in general consists of an assemblage of certain siliceous stones, such as quartz, schorl, feld spar, mica, &c.; and the more or less considerable magnitude of these elements of granite, has caused it to be divided into coarse-grained granite, and fine-grained granite.

It appears to me that there is no denying but that these rocks owe their arrangement to water: and if we may be permitted to recur, by an effort of the imagination\*, to that epocha in which, according to sacred and profane historians, the water and earth were confounded, and the confused mixture of all principles formed a chaos, we shall see that the laws of gravity inherent in matter must have carried it down, and necessarily produced the arrangement which observation at present exhibits to us. The water, as the least heavy, must have purified itself, and arisen to the surface by a filtration through the other materials: while the earthy principles must have precipitated, and formed a mud, in which all the elements of stones were confounded. In this very natural order of things, the general law of affinities, which continually tends to bring together all analogous parts, must have exerted itself with its whole activity upon the principles of this almost fluid paste; and the result must have been a number of

\* This is the first and the last supposition in which I shall indulge myself. It is a conjecture, however, which is indifferent with respect to the basis of the subject itself; since it relates only to an hypothesis respecting the manner in which a rock might be formed that at present exists, and whose decompositions alone can form the subject of our observations.



bodies of a more definite kind, in crystals more or less regular: and from this muddy substance, in which the principles of the stones were confounded that compose the granite, a rock must have been produced, containing the elementary stones all in possession of their distinct forms and characters. In this manner it is that we observe salts of very different kinds develop themselves in waters which hold them in solution; and in this manner it still happens that crystals of spar and gypsum are formed in clays which contain their component parts.

It may easily be conceived that the laws of gravitation must have influenced the arrangement and disposition of the products. The most gross and heavy bodies must have fallen, and the lightest and most attenuated substances must have arranged themselves on the surface of the foregoing; and this it is which constitutes the primitive schisti, the gneis, the rocks of mica, &c. which commonly repose upon masses of coarse-grained granite.

The disposition of the fine-grained granite in strata or beds, appears to me to depend on this position, and the fineness or tenuity of its parts. Being placed in immediate contact with water, this fluid must naturally have influenced the arrangement which it presents to us; and the elements of this rock being subjected to the effect of waves, and the action of currents, must have formed strata.

The rocks of granite being once established as the nucleus of our globe, we may, from the analysis of its constituent principles, and by attending to the action of the various agents capable of altering it, follow the degradations to which it has been subjected, step by step.

Water is the principal agent whose effects we shall examine.

This fluid, collected in the cavity of the ocean, is carried by the winds to the tops of the most elevated mountains, where it is precipitated in rain, and forms torrents, which return with various degrees of rapidity into the common reservoir.

This uninterrupted motion and fall must gradually attenuate and wear away the hardest rocks, and carry their pulverulent parts to distances more or less considerable. The action of the air, and varying temperatures of the



atmosphere, facilitate the attenuation and the destruction of these rocks. Heat dries their surface, and renders it more accessible and more penetrable to the water which succeeds; cold divides them, by freezing the water which has entered into their texture; the air itself affords the carbonic acid, which attacks the lime-stone, and causes it to effloresce; the oxigene unites to the iron, and calcines it: insomuch that this concurrence of causes favours the disunion of principles; and consequently the action of water, which clears the surface, carries away the products of decomposition, and makes preparation for a succeeding process of the same nature.

The first effect of the rain is therefore to depress the mountains. But the stones which compose them must resist in proportion to their hardness; and we ought not to be surprised when we observe peaks which have braved the destructive action of time, and still remain to attest the primitive level of the mountains which have disappeared. The primitive rocks, alike inaccessible to the injury of ages as to the animated beings which cover less elevated mountains with their remains, may be considered as the source or origin of rivers and streams. The water which falls on their summits, flows down in torrents by their lateral surfaces. In its course it wears away the soil upon which it incessantly acts. It hollows out a bed, of a depth proportioned to the rapidity of its course, the quantity of its waters, and the hardness of the rock over which it flows; at the same time that it carries along with it portions and fragments of such stones as it loosens in its course.

These stones, rolled along by the water, must strike together, and break off their projecting angles: a process that must quickly have afforded those rounded flints which form the pebbles of rivers. These pebbles are found to diminish in size, in proportion to the distance from the mountain which affords them; and it is to this cause that Mr. Dorthes has referred the disproportionate magnitude of the pebbles which form our ancient worn stones, when compared with those of modern date: for the sea extending itself formerly much more inland, in the direction of the Rhone, the stones which it received from the rivers, and threw back again upon the shores, had not run through so

long a space in their beds as those which they at present pass over. Thus it is that the remains of the Alps, carried along by the Rhone, have successively covered the vast interval comprised between the mountains of Dauphiny and Vivarais; and are carried into our seas, which deposit them in small pebbles on the shore.

The pulverulent remains of mountains, or the powder which results from the rounding of these flints, are carried along with greater facility than the flints themselves: they float for a long time in the water, whose transparence they impair; and when these same waters are less agitated, and their course becomes slackened, they are deposited in a fine and light paste, forming beds more or less thick, and of the same nature as that of the rocks to which they owe their origin. These strata gradually become drier by the agglutination of their principles; they become consistent, acquire hardness, and form siliceous clays, flex, petrosilex, and all the numerous class of pebbles which are found dispersed in strata, or in banks, in the ancient beds of rivers.

Mr. Pallas has observed the transition of clay to the state of flex in the brook of Sunghir, near Wolodimir. Mr. J. W. Baumer has likewise observed it in Upper Hesse.

The mud is much more frequently deposited in the interstices left between the rounded flints themselves, which intervals it fills, and there forms a true cement that becomes hard, and constitutes the compound stones known by the name of pudding-stones and grit-stones; for these two kinds of stone do not appear to me to differ but in the coarseness of the grain which forms them, and the cement which connects them together.

We sometimes observe the granite spontaneously decomposed. The texture of the stones which form it has been destroyed; the principles or component parts are disunited and separated, and they are gradually carried away by the waters. I have observed near Mende, towards Castlenouvel, the most beautiful kaolin on the surface of a granite, in a state of decomposition; and this same rock is decomposed in several other parts of our province. It appeared to me that the feld spar was particularly subject to be altered the first.

Most siliceous stones, formed by the deposition of fluviatile waters, and hardened by the lapse of time, are easily subjected to a second decomposition. Iron is the principal agent of these secondary alterations; and its calcination, determined by air or water, produces a diffusion of principles. Nature may be observed in this process, by an attentive examination of such alterations as gun flints, variolites, porphyries, jaspers, and the like are subjected to.

The decomposition of flints calcedonies, agates, and generally all stones of this kind which possess a certain degree of transparence, appears to me to be referable to the volatilization of the water, which forms one of their principles, and is the cause of their transparency.

These stones may be considered as commencements of crystallization; and, when the water is dissipated, they effloresce after the manner of certain neutral salts. Hence it arises that the decomposition is announced by opacity, a white colour, loss of consistence and hardness; and terminates by forming a very attenuated powder, sometimes of extreme whiteness. It is this decomposition, more particularly, which forms clays.

There are flints whose alterations form effervescent marles. These do not appear to me to be of the nature of primitive rocks: they have the same origin as the calcareous stones, from which they differ only in consequence of a very considerable proportion of clay. The stones which we so abundantly find of this nature around us, among calcareous decompositions, may be considered as of this kind.

Water filtrating through mountains of primitive rock, frequently carries along with it very minutely divided particles of quartz; and proceeds to form, by deposition, stalactites, agates, rock crystal, &c.

These quartzose stalactites differently coloured, are of a formation considerably analogous to that of calcareous alabasters; and we perceive no other difference between them than that of their constituent parts.

II. Thus far we have exhibited, in a few words, the principal changes, and various modifications, to which the primitive rocks have been subjected. We have not yet observed either germination or life; and the metals,



fulphur, and bitumens, have not hitherto presented themselves to our observation. Their formation appears to be posterior to the existence of this primitive globe; and the alterations and decompositions which now remain to be enquired into, appear to be produced by the class of living or organized beings.

On the one hand, we behold the numerous class of shell animals, which cause the stony mass of our globe to increase by their remains. The spoils of these creatures, long agitated and driven about by the waves, and more or less altered by collision, form those strata and banks of limestone, in which we very often perceive impressions of those shells to which they owe their origin.

On the other hand, we observe a numerous quantity of vegetables that grow and perish in the sea; and these plants likewise, deposited and heaped together by the currents, form strata, which are decomposed, lose their organization, and leave all the principles of the vegetable confounded with the earthy principle. It is to this source that the origin of pit-coal, and secondary schistus, is usually attributed; and this theory is established on the existence of the texture of decomposed vegetables very usually seen in schisti and coal, and likewise on the presence of shells and fish in most of these products.

It appears to me that the formation of pyrites ought to be attributed to the decomposition of vegetables: it exists in greater or less abundance in all schisti and coal. I have found a wooden shovel buried in the depositions of the river De Ceze, converted into jet and pyrites. The decomposition of animal substances may be added to this cause: and it appears to me to be a confirmation of these ideas, that we find many shells passed to the state of pyrites.

Not only the marine vegetables form considerable strata by their decomposition; but the remains of those which grow on the surface of the globe, ought to be considered among the causes or agents which concur in producing changes upon that surface.

We shall separately consider how much is owing to each of these causes; and shall follow the effects of each, as if that cause alone were employed in modifying and altering our planet.



1. The calcareous mountains are constantly placed upon the surface of the primitive mountains; and though a few solitary observations present a contrary order, we ought to consider this inversion and derangement as produced by shocks which have changed the primitive disposition. I must observe also that the disorder is sometimes merely apparent; and that some naturalists of little information have described calcareous mountains as inclining beneath the granite, because this last pierces, as it were, through the envelope, rises to a greater height, and leaves at its feet, almost beneath it, the calcareous remains deposited at its base.

Sometimes even the lime-stone fills to a very great depth the crevices or clefts formed in the granite. I have seen in Gevaudan, towards Florac, a profound cavity in the granite filled with calcareous stone. This vein is known to possess a depth of more than one hundred and fifty toises, with a diameter of about two or three.

It likewise happens frequently enough that such waters as are loaded with the remains of the primitive granite, heap them together, and form secondary granites, which may exist above the calcareous stone.

These calcareous mountains are decomposed by the combined action of air and water; and the product of their decomposition sometimes forms chalk or marle.

The lightness of this earth renders it easy to be transported by water; and this fluid, which does not possess the property of holding it in solution, soon deposits it in the form of gurhs, alabasters, stalactites, &c. Spars owe their formation to no other cause. Their crystallization is posterior to the origin of calcareous mountains.

Waters wear down and carry away calcareous mountains with greater ease than the primitive mountains; their remains being very light, are rolled along, and more or less worn. The fragments of these rocks are sometimes connected by a gluten or cement of the same nature; from which process calcareous grit and breccias arise. These calcareous remains formerly deposited themselves upon the quartzose sand; and the union of primitive matter, and secondary products, gives rise to a rock of a mixed nature, which is common in our province.

2. The mountains of secondary schistus frequently exhibit to us a pure mixture of earthy principles, without the smallest vestige of bitumen. These rocks afford, by analysis, silica, alumina, magnesia, lime in the state of carbonate, and iron; principles which are more or less united, and consequently accessible in various degrees to the action of such agents as destroy the rocks hitherto treated of.

These same principles when disunited, and carried away by waters, give rise to a great part of the stones which we have comprised in the magnesian genus. The same elements, worn down by the waters, and deposited under circumstances proper to facilitate crystallization, form the schists, tourmaline, garnets, &c.

We do not pretend by this to exclude and absolutely reject the system of such naturalists as attribute the formation of magnesian stones to the decomposition of the primitive rocks. But we think that this formation cannot be objected to for several of them, more especially such as contain magnesia in the greatest abundance.

It frequently happens that the secondary schists are interspersed with pyrites; and, in this case, the simple contact of air and water facilitates their decomposition. Sulphuric acid is thus formed, which combines with the various constituent principles of the stone; whence result the sulphates of iron, of magnesia, of alumina, and of lime, which effloresce at the surface, and remain confounded together. Schists of this nature are wrought in most places where alum works have been established; and the most laborious part of this undertaking consists in separating the sulphates of iron, of lime, and of magnesia from each other, which are mixed together. Sometimes the magnesia is so abundant that its sulphate predominates: I have seen mountains of schistus of this nature. The sulphate of lime being very sparingly soluble in water, is carried away by that liquid, and deposited to form gypsum; while the other more soluble salts remaining suspended, form vitriolic mineral waters.

The pyritous schists are frequently impregnated with bitumen, and the proportions constitute the various qualities of pit coal.

It appears to me that we may lay it down as an incontestable principle, that the pyrites is abundant in proportion as the bituminous principle is more scarce. Hence it arises, that coals of a bad quality are the most sulphureous, and destroy metallic vessels by converting them into pyrites. The focus of volcanos appears to be formed by a schistus of this nature; and in the analyses of the stony matters which are ejected we find the same principles as those which constitute this schistus. We ought not therefore to be much surprised at finding schorls among volcanic products; and still less at observing that subterranean fires throw sulphuric salts, sulphur, and other analogous products out of the entrails of the earth.

3. The remains of terrestrial vegetables exhibit a mixture of primitive earths more or less coloured by iron: we may therefore consider these as a matrix in which the seeds of all stony combinations are dispersed. The earthy principles assort themselves according to the laws of their affinities; and form crystals of spar, of plaster, and even the rock crystals, according to all appearance: for we find ochreous earths in which these crystals are abundantly dispersed; we see them formed almost under our eyes. I have frequently observed indurated ochres full of these crystals terminating in two pyramids.

The ochreous earths appear to me to deserve the greatest attention of naturalists. They constitute one of the most fertile means of action which nature employs; and it is even in earths nearly similar to these that she elaborates the diamond, in the kingdoms of Golconda and Visapour. If it were allowable to indulge in a fiction purely poetical, we might affirm that the element of fire, so far from being lost by the dispersion of the combustible principles of vegetables, becomes purified to form this precious stone so eminently combustible; that nature has been desirous of proving that the terms Destruction and Death are relative only to the imperfection of our senses; and that she is never more fruitful than when we suppose her to be at the moment of extinction.

The spoils of animals, which live on the surface of the globe, are entitled to some consideration among the number of causes which we assign to explain the various changes

our planet is subjected to. We find bones in a state of considerable preservation in certain places; we can even frequently enough distinguish the species of the animals to which they have belonged. From indications of this sort it is that some writers have endeavoured to explain the disappearance of certain species; and to draw conclusions from thence, either that our planet is perceptibly cooled, or that a sensible change has taken place in the position of the axis of the earth. The phosphoric salts and phosphorus which have been found, in our time, in combination with lead, iron, &c. prove that, in proportion as the principles are disengaged by animal decomposition, they combine with other bodies, and form the nitric acid, the alkalis, and in general all the numerous kinds of nitrous salts.



## PART THE THIRD.

### CONCERNING METALLIC SUBSTANCES.

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#### INTRODUCTION.

**M**ETALLIC substances are distinguished from all the other productions of our globe, by an absolute opacity, a much greater specific gravity than that of any other substance, and a degree of brilliancy peculiar to bodies of this class.

The multiplicity of uses to which metals are applied in the arts, and in medicine, as well as the place which they occupy in the natural history of our planet, render the study of them both interesting and necessary.

1. One of the distinctive characters of metals is their opacity. The most opaque stone, divided into very thin laminæ, becomes transparent; whereas the thinnest plate of metal preserves the same opacity as the mass itself\*. This truly characteristic property has induced artists to employ metals to reflect the images of objects. A thin covering of tin and mercury fixed on the surface of a glass, forms a mirror or looking-glass; and well-polished steel constitutes the mirrors of telescopes\*. The hardness of a

\* Gold excepted; which, when beaten into leaf of about the two hundred and eighty thousandth part of an inch in thickness, transmits light of a beautiful green colour. It is highly probable that other metals would become transparent if they could be mechanically divided, or beaten out into laminæ of sufficient thinness, or if artists had sufficient motives to attempt it.

See Newton on Light and Colours, for the proofs on which he grounds his general inference—that all bodies are transparent when sufficiently divided. T.

metal contributes singularly to facilitate the reflection of objects, as it renders it capable of taking a very fine polish, but its colour must necessarily concur to render it perfect; for these tinges cause it to absorb a greater or less quantity of the rays. The great defect of metallic mirrors is, that their surface becomes tarnished by the inevitable alteration which the action of the air and moisture must produce.

2. The relative weight is likewise a character by which we may distinguish a metallic substance. A cubic foot (French) of marble weighs 190 pounds (livres); a cubic foot of tin weighs 510; and a cubic foot of gold 1348.

The metals, in general, likewise possess the facility of being extended and flattened when struck, or subjected to a strong and gradual pressure: this property is known by the name of Ductility. All the metals do not possess this quality; but those which possess the metallic qualities most eminently, exhibit this likewise. We may distinguish three states of ductility relative to the manner in which it is modified by various known processes. 1. Ductility under the hammer. 2. Ductility through the plate of the wire-drawer. 3. Ductility between the laminating rollers.

Metals ductile under the hammer present themselves in the following order: Gold, Silver, Copper, Iron, Tin, and Lead.

Metals ductile through the wire-drawer's plate form the following series: Gold, Iron, Copper, Silver, Tin, and Lead.—As, in the operation of wire-drawing, the metal is strongly drawn, to cause it to pass through holes of various diameters, and to reduce it into threads, the metals do not resist this prodigious extension but in proportion to their greater or less tenacity. Mr. De Fourcroy has therefore distinguished this ductility from the foregoing, by attributing it merely to the tenacity of the metals.

\* I do not find that steel has ever been in general use for reflecting telescopes, though it has doubtless been tried among the many experiments made for the improvement of these instruments. A kind of bell-metal, consisting of one-third tin, and two-thirds copper, is commonly employed for this purpose: the addition of about a fiftieth part of arsenic singularly contributes to the closeness of its grain. On this subject consult the Treatise of Mr. Edwards, annexed to the Nautical Almanac for 1787. T.

There are some metals which are not ductile either under the hammer or through the wire-drawer's plate, but become very considerably so when an equal and gradual pressure is applied. Zinc is of this nature. Mr. Sage has reduced it into very thin and very flexible leaves, by passing it between the laminating cylinders.

Heat assists the ductility of all metals, by separating their integrant parts, and forming spaces or interstices which permit the compressed molecules to flatten and extend themselves. This circumstance has induced artists to avail themselves of the assistance of heat in the working of metals. Without this precaution they would either become hard, or crack; because the particles, being too near each other would be no longer capable of giving way under the hammer.

The ductility of metals permits us to fashion them as we think fit; and it is upon this admirable property that almost all the arts are founded which relate to the working of metals. Without this property, metallic bodies would consist either of shapeless masses, or large pieces of such figures as casting might produce. But we should be deprived of the number of various objects which the arts have successively afforded to supply our wants or luxuries.

Nature very seldom presents us with metals possessed of the degrees of perfection here enumerated. She has concealed them in the bowels of the earth, combined with various substances; which, by masking or changing the metallic properties, have left to the industry of man the laborious task of extracting them, clearing them of their original combinations, and giving them the valuable qualities which are peculiar to metals. The metals, thus buried and concealed, form ores. These ores usually exist in clefts or crevices of rocks, which are distinguished by the name of Veins. These veins are more or less inclined to the horizon; and the degrees of inclination have caused them to be distinguished by the names of direct, oblique, inclined, or level veins, according to the angle they make with the horizon. The part of the rock which rests upon the superior part of the vein, is called the Roof; and that part upon which the vein itself rests, is called the Bed of the vein. These veins are of various breadths, and are accordingly distinguished by the names of Slips or Veins.

They possess a greater or less degree of continuity, according to which they are distinguished by the names of continued or broken veins; and when the ore is found in spherical parts or masses, from space to space, these masses are called Bellies or Stock-works. A vein which does not penetrate to a considerable depth in the earth, is called by us *Coureur de Gazon*.

The characters from which mineralogists pretend to assert the existence of an ore in the bowels of the earth, are all equivocal and suspicious. The savage aspect of a mountain, the nature of the plants which grow upon it, the exhalations which arise from the earth, all afford characters too doubtful for a reasonable man to risk his fortune upon such indications alone. The dipping wand, or divining rod, is the fruit of superstition and ignorance: and the ridicule which has been successively thrown upon this class of impostors, has diminished their number; at the same time that the numerous dupes of this class of men have rendered their successors more prudent.

The nature of the stones which compose a mountain is capable of furnishing some indications. We know, for example, that ores are seldom found in granite, and the other primitive mountains; we know likewise that mountains of too modern a formation contain them very rarely; and we find them only in secondary mountains, in which the schistus and ancient calcareous stone are void of all impressions of shells.

The presence of ponderous spar, forming a stratum or vein at the surface of the earth, has been considered by many mineralogists as a very good indication. It appears to me even that this stone is the same which Becher has spoken of in his works, under the name of Vitriifiable Earth, which he considered as a principle of metals; and that it has been very improperly taken for quartz by his readers.

The vitriifiable stone of Becher—"lapidis species quæ in igne fluit, et fluens vitrum exhibet,"—and elsewhere, "transparens enim nonnihil est, albus, et quasi, argenteis foliis interspersus, ad ignem faciliè liquabilis,"—was considered by him as a certain indication of the presence of ores, as appears by the following passage: "Sine quo



lapide, nulla minera bona est, nec fertilitatem promittit; adeo enim iste lapis mineris necessarius est, ut vel nudè, et sine ullo metallo, in montibus existens, infallibile signum futuri metalli sit; quod, hoc signo freti, non sine magnis, interdum sumptibus, quærent minerarum indagatores; hanc ergo sive terram sive lapidem, non sine prægnantibus causis, pro principio primo omnium metallorum, minerarum, et lapidum ac gemmarum, statuimus et agnoscimus; certis freti experimentis, ut in sequentibus demonstrabimus, quibus evincere possumus præfatam terram actu in metallis et mineralibus omnibus, nec non lapidibus et gemmis, existere, eorumque mixtum ut basim et fundamentum ingredi; unde ea hypostasim suam, oppositam, diaphaneitatem, et fluxum nanciscuntur . . . . . Hæc ergo terra non modo cum præfens adest infallibile signum affuturi metalli est, sed et absens idem signum existit, defuturi nempe metalli . . . . . defectus hujus terræ proxima et frequentissima causa sterilitum minerarum existit . . . . lapis de quo egimus, non modo ut matrix sed ut ingrediens et principium.”

When we possess indications of the existence of an ore in any place, we may use the borer, to confirm or destroy these suspicions, at a small expence.

It frequently happens that the veins are naked or uncovered: the mixture of stones and metals forms a kind of cement which resists the destructive action of time longer than the rest of the mountain; and as these parts of rocks, connected by a metallic cement, present a stronger resistance to the action of waters, which incessantly corrode and diminish mountains, and carry away their parts into the sea, we frequently observe the veins projecting on the sides of the mountains incrustated with some slight metallic impression altered by the lapse of time.

Before we proceed to treat of metallic works in the large way, it will be proper to explain the methods of judging of the nature and value of an ore, in order that the members of society may not rashly hazard their fortunes. The nature of an ore is judged from inspection. A slight acquaintance with this subject is sufficient to enable the observer to form an immediate judgment of the nature of an ore. The blow-pipe is an instrument by the assistance of which we may in a short space of time become

acquainted likewise with the species of the ore. This knowledge forms the docimastic art, or docimasia. In order to make the assay of an ore, in general (for all ores do not require the same process, as we shall hereafter observe), small pieces of the mineral are examined. These are cleared from foreign and stony substances as much as possible. The pure mineral is then pounded, and a certain quantity weighed, which is torrefied in a vessel larger and less deep than a common crucible. By this means the sulphur or the arsenic in combination with the metal are dissipated; and by the loss of weight resulting from the calcination, a judgment is formed of the proportion of foreign volatile matter it contained.

This first operation shews the proportion and quantity of sulphur and arsenic which may be mixed with the metal. The sulphureous smell may easily be distinguished from the smell of garlic, which characterizes arsenic. These foreign substances mixed with the metal are called Mineralizers.

In order to obtain an accurate judgment of the weight of the mineralizer, the augmentation in weight which the metal has undergone in passing from its metallic state to that of oxide or calx, must be added to the loss occasioned by the calcination.

Two hundred grains of this roasted ore are then to be taken, and mixed with fluxes capable of fusing and reducing it. In this operation a crucible is made use of; and a sufficient degree of heat being applied, the metal is precipitated to the bottom of the crucible in a button, whose weight indicates the quantity of metal contained in the ore.

These fluxes must be varied according to the nature of the ores under examination. It is necessary that they should all contain the coaly principle, to disengage the oxigene with which these metals are impregnated by the calcination. But the nature of the flux must be varied according to the fusibility of the metal. The three following will answer all these purposes.

1. The fusible material called black flux is made with two parts of tartar, and one part of nitre melted together. The coaly and alkaline residue is used to reduce the ores of lead, copper, antimony, &c.

2. Two hundred grains of calcined borax, one hundred grains of nitre, twenty grains of flacked lime, and one hundred grains of the ore intended to be assayed, form the flux of Scopoli, of which I have found the advantage in the assay of iron ores.

The vitreous flux of Mr. De Morveau, made with eight parts of pounded glass, one of borax, and half a part of powder of charcoal, may be employed for the same purpose.

3. Arsenic and nitre, in equal parts, form likewise a very active flux.

The neutral arsenical salt has been used with success to fuse platina.

As soon as the existence of a mine, and its nature and riches, are ascertained, it is in the next place necessary to be assured of a sufficient abundance and continuity of water to answer the purposes of the works. It is likewise necessary to be assured of possessing a sufficient quantity of wood or charcoal; and, more especially, a good director must be procured: for, in my opinion, a poor mine well managed is preferable to a rich one ill conducted.

These preliminary circumstances being accomplished, the most simple and least expensive processes must be employed in extracting the mineral from the bowels of the earth. For this purpose, shafts or galleries must be dug, according to the position of the vein, and the nature of its situation.

When it is practicable to arrive at the side of the vein, and at a certain depth, by a horizontal gallery, the works become more simple and economical; the same opening serving to draw off the waters, and extract the ore. Galleries are then to be carried on to the right and left; and shafts sunk, which communicate with the open air, as likewise others carried down into the vein. Galleries are likewise constructed, one above the other, and the communication of the works kept up by ladders. When the soil is friable, and defective in solidity, care must be taken to support it with timbers of sufficient strength, to prevent its falling in.

Pickaxes, wedges, and levers are used to detach the ore, when the rock is soft; but it is most commonly necessary to employ gunpowder, and to form mines.



Want of air, and the abundance of water, are almost always noxious, and derange mine-works. The water is carried off by fire-engines, wind-mill pumps, and other suitable apparatus.

Currents of air are produced by establishing communications with the galleries by horizontal apertures. Furnaces erected on the side of a shaft, to which a long tube is adapted at one end, communicating with the ash-hole, and at the other plunging into the shaft to draw up the air, or ventilators placed in the same situation, answer a similar purpose. The foul air is destroyed by rendering a lixivium of ashes caustic; and sprinkling quick-lime about the mine likewise produces the same effect.

A prudent company ought to extract the largest possible quantity of ore, before they determine upon constructing the necessary works for the subsequent processes. We cannot see into the bowels of the earth. Appearances are often deceitful; and we have seen companies either ruined or discouraged, because they had employed immense sums to construct the necessary furnaces to work an ore whose existence was doubtful. When the proceedings, in an undertaking of this kind, are carried on with proper precaution, and no more expence is entered into than what the ore extracted, and of a known value, is capable of representing, the probable losses are very slight, even in the poorest mine.

The works ought to be varied according to the nature and state of the mineral. It is found in three states—1. In the form of a native metal: in this case, nothing more is necessary than to extract it out of the mine, to clear it of the extraneous substances, and to fuse it. 2. In the form of calx or oxide; and in this state it is sufficient if it be sorted and fused. 3. Combined with sulphur or arsenic, in which case it must be made to undergo some other operations.

Although, in this last case, the works, subsequent to the extraction, vary according to the nature of the ore, there are nevertheless certain general operations to which every kind of ore is subjected, which we shall here speak of.

The metal is always mixed with stony substances, which are called the Gangue. The first business must therefore be to clear the metal of this foreign substance. For this



purpose, when the ore is extracted, children are employed who examine it, and separate the pure ore or rich mineral from that which is mixed with the gangue. As in this second quality the stone is mixed with the ore, the whole is pulverized by means of a stamping mill, consisting of pestles of wood, shod with iron, and armed with cocks, which are raised by levers proceeding from the axis of a wheel that constantly returns. The mineral is by this means crushed and pulverized; and a stream of water which is made to pass over it, carries away both the metallic and stony particles; the former being deposited in the first vessels through which the water is made to circulate, while the latter or stony part is carried to a greater distance on account of its lightness.

This pulverized ore is called *Selich*; and, in order to separate all the earthy parts, it is washed upon tables slightly inclined, over which a constant stream of water is made to flow. The *selich* is agitated with brooms; the water carries away all the fragments of stone, and leaves the pure ore upon the table.

The calcination of the mineral succeeds the washing. In this operation the mineralizer is carried off. Fire is always the agent made use of. Sometimes the pounded mineral is disposed in piles upon heaps of wood, which, being set on fire, heat the ore strongly, and drive off the mineralizer. This calcination possesses the double advantage of disposing the metal for fusion, as well as clearing it of the mineralizing substance. When the ore is more friable, it is spread out in a reverberatory furnace; and the flame which reverberates upon it deprives it of its mineralizer, at the same time that it partly fuses it.

Mr. Exchaquet has proposed to destroy the sulphur by nitre. This process is excellent for copper ores. The quantity of nitre varies according to the quantity of sulphur; but there is no danger of adding too much. In this operation the mixture is thrown into an ignited crucible, and kept at a moderate heat for some minutes.

The fusion is effected in furnaces, excited by a current of air, kept up by means of large bellows, or a machine called a *trompe*.

The *trompe*, or blowing machine\*, is formed of a hollow tree which rests upon a cask whose lower head is knocked out, and the open part of the cask itself plunged to a certain depth under water. A current of water is made to fall through this wooden trunk upon a stone which is erected in the middle of the cask. The air becomes disengaged, and is obliged to pass out at a collateral aperture in the cask, by means of a tube which carries it to the lower part of the furnace. This air is afforded.—1. By that air which the water carries along with it. 2. By a current which passes through apertures made at the distance of six feet from the summit of the tree, and called *trompilles*.

The dimensions of a good *trompe* are the following:

Length of the tree or wooden trunk, from its summit to the side apertures or *trompilles*, six feet.

Length of the tree from the *trompilles* to the cask, eighteen feet.

Height of the cask, five feet.

Diameter of the cask, four feet six inches.

The form of the internal part of the trunk above the *trompilles*, is that of a funnel, whose superior opening is eighteen inches, and its inferior diameter five.

The diameter of the cavity of the tree, below the *trompilles*, is eighteen inches.

The diameter of the *trompilles* is six inches.

The stone upon which the water falls is eighteen inches in diameter.

When the mineral is once cleared of its gangue, its mineralizer, and all other foreign matter, it constitutes what is called a metal, or *regulus*.

Every fact appears to prove that metals are simple substances; the various alterations to which they are subjected, being combinations of the metal itself with other substances. None of these operations either disengage or separate any constituent part of the metal itself, as we shall see.

Every metal is fused at a certain degree of heat, more or less intense; and in this situation their surface is convex.

\* I do not find in Lewis's *Commerce of Arts*, where this subject is well treated, that the English have called this machine by any appropriated name. T.

Messrs. Macquer and Lavoisier having exposed gold to the focus of the lens of Tschirnhausen, observed that this metal exhaled in fumes, without being decomposed; as was proved by collecting it unaltered upon presenting a plate of silver, which became gilt. Silver is volatilized in the same manner without decomposition.

Metals fused, and cooled slowly, exhibit crystallizations of considerable regularity. The abbé Mongez, and Mr. Brogniart, have succeeded in crystallizing most of them, by varying the process used by the celebrated Roule in the crystallization of sulphur.

Most metals kept in a state of fusion lose their metallic brilliancy, and become converted into an opaque powder called Oxide, or Metallic Calx. The oxides, when urged by a stronger heat, are reduced into a vitriform substance, known by the name of Metallic Glass.

Metals acquire weight in their transition to the state of oxide. This circumstance has led several adepts into error, who imagined they had increased the weight of the metal.

Geber observes, "*Ubi vel minimum augmenti metallici inveneris, ibi te dicimus esse ante fores philosophorum.*"—"Et sane conveniens judicium est," adds Becher; "*id enim per quod corpus homogeneum augmentum capit, id ipsum est quod pro principio istius corporis haberi potest.*"—*Phys. Subt.*

Stahl pretended that the calcination of metals arose from the disengagement of phlogiston; and he considered their calces as an earth, or metallic basis.

Boyle affirmed that the increase of weight in calcined metals was owing to the combination of the matter of fire; and Boerhaave ventured to attribute it to the surrounding bodies, which deposited themselves upon the metal. Of all the hypotheses which have been formed upon this subject, that of Stahl has met with the greatest number of supporters: and the blind zeal of his followers has carried them so far as even to disguise an unanswerable objection; namely, that it can never be explained how metals, by the loss of one principle, at the same time that they do not acquire another, can become heavier. The reduction of the oxides or metallic calces, without any addition of the charcoal, cannot be explained on this hypothesis.



It must be confessed that all chemists were not of this way of thinking: and we find in the writings of Jean Rey, a Physician of Perigord, that he, in the year 1630, attributed the increase of weight in calcined metals to the combination of air with the metal. He affirms that agitation facilitates this combination in no other manner than water renders the sand heavy which is thrown and agitated in that fluid.

He reasons like a chemist of considerable skill, to prove that the increase of weight cannot be carried beyond a point of saturation; and he concludes his observations in these words: *Le travail a été mien; le profit en soit au lecteur, et à Dieu seul la gloire*—"Mine has been the labour; let the reader enjoy the advantage, and to God alone be the glory\*."

All these several sketches were never formed into a connected system; and this doctrine was even completely unknown, when Mr. Lavoisier proved to us that the calcination of metals was owing merely to the fixation of oxygenous gas, and their reduction to the disengagement of this gas, effected by simple heat, or by its combination with various bases in such instances wherein its adhesion to the metal is too strong to be overcome by mere heat. The proofs upon which this celebrated chemist has established his opinion, are the following facts.

1. Metals are not oxidized either in a vacuum, or in air which contains no part of oxygenous gas. The Count Morozzo, Priestley, Lavoisier, and Berthollet appear to have oxidized lead, tin, and mercury in the carbonic acid. See the Memoir of Mr. Sennebier, *Journal de Physique*, Février 1787.—But this pretended oxide is nothing but a metallic carbonate, or the combination of a metal with an acid, which is very far from calcination or oxidation.

2. Metals inclosed under a glass, and properly heated, are oxidized only by absorbing the oxygenous gas contained in the mass of air which is insulated; and when this absorption is ended, it is impossible to carry the oxidation any further.

3. Metals oxidized in an atmosphere of oxygenous gas absorb it to the last drop.

\* This is the same Jean Rey, who, being under the necessity of contradicting his friend Libavius on the theory of the calcination of metals, exclaims—"O Truth, how dear art thou to me! since it is in thy power to make me enter into a contest with so dear a friend."



4. Such oxidized metals as are capable of being reduced in closed vessels, give out, on their return to the metallic state, the same quantity of oxygenous gas as they had before absorbed.

This doctrine appears to me to be established on the the most complete series of proofs which can be desired in matters capable of demonstration.

The concurrence of air and of humidity singularly assists the alteration of metals. The water is decomposed in this process, and its hydrogen is dissipated, while its oxygen combines with the metal. This is doubtless the theory of such oxidations as are effected beneath the surface of water; and when we find oxides, or metallic calces, in the bowels of the earth, defended from the contact of air, the facts ought to be referred only to the decomposition of water, or of acids which have oxygen for their base.

Hence it follows that the alteration of a metal will be the more speedy—1. In proportion as the affinity of the metal to oxygenous gas is stronger. 2. As the quantity of oxygenous gas is greater. 3. As the air is more humid, &c. Metals decompose certain substances in order to unite with their oxygen, and by that means to pass to the state of oxide. This is observable when the nitric acid is digested upon certain metals.

Metallic substances being considerably numerous, it is necessary to class them, that we may bring together such as possess similar properties, and separate others which differ from them.

Ductility serves as a leading character. Metals may be distinguished into such as are ductile, and such as do not possess this property. The name of Metal has been peculiarly applied to the former, and that of Semi-metal to the latter kind.

Among the metals there are some which are changeable by exposure to air, while others are not sensibly altered in the same situation. This difference has caused a subdivision of the metals into perfect and imperfect metals.

We shall begin by treating of the semi-metals, because for the most part they approach to the saline or stony substances in their qualities; and we shall conclude with the perfect metals, because they possess the metallic qualities in an higher degree.

## CHAPTER I.

*Concerning Arsenic.*

THE substance which is sold in commerce under the name of arsenic, is a metallic oxide of a glittering whiteness, sometimes of a vitreous appearance; exciting an impression of an acrid taste on the tongue; volatile when exposed to fire, in which situation it rises in the form of a white fume, with a very evident smell of garlic.

Although arsenic is most commonly met with under this form, it may be reduced to the metallic state by treating it with oils, soaps, or charcoal in closed vessels. The celebrated Becher was perfectly acquainted with this process —“ Si oleum, vel quodcunque pingue, arsenico misceas, et per retortam distilles urgenti igne, sublimabitur in colum arsenicum, insignitur antimonii instar metallizatum.” —The arsenic which sublimes is of a brilliant grey colour, resembling steel, but it speedily becomes black in the air: it forms crystals, which Mr. De Lisle considers as alumiform octahedrons.

Arsenic is sometimes found native; and it is met with in stalactites, or in protuberant depositions formed of layers more or less distinct and concentric, which are separable from each other like the coats of an onion, or the laminæ of shells, from which it has obtained the name of testaceous arsenic. In other instances the masses are formed of very small scales; which renders the surface of the specimen sometimes granulated, and sometimes full of small cavities: it is then called scaly arsenic. Arsenic is also found in friable masses, possessing scarcely any consistence. In these various forms we receive it from Bohemia, Hungary, Saxony, Saint Marie aux Mines, &c.

Arsenic is volatilized by an heat of about 144 degrees of Reaumur. In order to set fire to this metal, it must be thrown into a crucible strongly ignited; and then it exhibits a blue flame, and rises in the form of a white oxide.

If it be sublimed by a gentle heat, it crystallizes in rhedral pyramids or in octahedrons.

Arsenic is not soluble in water. Its specific gravity is 57633, according to Briffon. Its fracture resembles that of steel, but it easily tarnishes.

Arsenic appears to exist in the metallic state in its combinations with cobalt in the testaceous cobalt ore, or with iron in mispickel, according to the observation of Bergmann.

Arsenic unites by fusion with most of the metals; but those which were ductile before this addition, become brittle afterwards. Those which are of difficult fusion alone flow more easily by heat with the addition of arsenic, and those which are very fusible become refractory by the same addition. The yellow or red metals become white with this alloy.

Arsenic is often combined with metals in various ores, and is disengaged from them by calcination. In various mine works, long winding chimneys are constructed, through which the arsenical vapours pass, and in which they attach themselves. The crust which is formed in process of time against the internal surface of these chimneys is taken away, and is the substance met with in commerce under the name of arsenic. The cobalt ores of Saxony, which are torrefied to separate this semi-metal, afford almost the whole of what is sold. This oxide of arsenic is sometimes native, and has been found in Saxony and Bohemia. It is very abundant in such places as are situated in the vicinity of subterranean fires, such as the Solfatara. It is often found crystallized in octahedrons, according to Mr. Sage.

The oxide is less volatile than the metal itself; and, as we have before observed, it emits a very evident smell of garlic. If it be sublimed by a strong fire in closed vessels, it becomes transparent like glass; but its surface is soon rendered opaque again by exposure to air. It is not rare to find arsenical glass in the arsenic of commerce: it is yellowish, and soon loses its transparency by exposure to air. This glass is sometimes found native in the cobalt mines, and among volcanic products.

Eighty parts of distilled water, at the temperature of twelve degrees, are required to dissolve one part of the oxide of arsenic; but fifteen are sufficient at the boiling heat.

One part of arsenic is soluble in between seventy and eighty parts of alcohol at the boiling heat.

The oxide of arsenic partakes therefore of the properties of saline substances, and differs from the other metallic oxides—1. Because it is perfectly soluble in water. 2. Because the other metallic oxides are without smell, and fixed in the fire. 3. Because those oxides do not contract any union with metals.

On the other hand it resembles the metallic oxides—1. In becoming converted into a metallic glass by a strong heat. 2. In forming an opaque insoluble substance, possessing the metallic brilliancy when deprived of oxygen.

The oxide of arsenic is capable of combining with sulphur; and the result is either orpiment or realgar, according to the manner of operating.

Most chemists have a notion that the realgar contains more sulphur than the orpiment; and they have prescribed different proportions to form these two substances. But it has been proved by Mr. Bucquet, that this difference of colour arises only from the manner of applying the fire; nothing more being necessary to convert orpiment into realgar, than the exposing it to a strong heat: and with the same mixture we may at pleasure obtain either of these products, according to the manner of applying the heat.

Orpiment and realgar are found native in certain places. Linnaeus, Wallerius, Bergmann, and Cronstedt have described them.

Crystals of realgar are found in Solfatara near Naples, according to Ferber; in the mines of Nagyag in Transylvania (see Forster's Catalogue; in the mines of Felsobanya in Upper Hungary; in those of Joachimstal in Bohemia, and of Marienburg in Saxony.

Realgar is common in China; it is made into vases, pagods, and other ornamental works. The Indians make use of these vessels to procure a purgative medicine: for this purpose they leave vinegar or lemon juice for several hours in the vessel, and afterwards drink it.

Realgar is commonly found in the waters of volcanos. I have almost always observed it in compressed hexahedral prisms, terminating in two tetrahedral summits.

Orpiment is less scarce than the realgar. It almost always accompanies this substance; but the orpiment of commerce comes to us from various countries up the Le-



vant, in irregular masses, solid or lamellated, and of a beautiful orange yellow. The Baron de Born informs us that it is met with, in polyhedral crystals, in a bluish clay near Newfol in Hungary.

Lime and the alkalis decompose these two substances, and disengage the oxide of arsenic.

The acids and the alkalis exhibit interesting phenomena with arsenic.

The sulphuric acid, when boiled on the oxide of arsenic, attacks and dissolves it; but this oxide is precipitated by cooling. If the whole of the acid be dissipated by a strong heat, the arsenical acid remains behind.

The nitric acid, assisted by heat, dissolves the oxide of arsenic, and forms a deliquescent salt, of which we shall presently treat.

The muriatic acid attacks arsenic very feebly. Messrs. Bayen and Charlard found its action very weak whether heated or cooled.

In order to form the sublimed muriate of arsenic, or butter of arsenic, equal parts of orpiment and corrosive sublimate of mercury are mixed together. The mixture is distilled by a gentle heat; and the receiver is found to contain a blackish corrosive liquor, which forms the sublimed muriate of arsenic. Cinnabar comes over if the heat be increased, according to the observation of Mr. Sage.

If pure pot-ash be boiled on the oxide of arsenic, the alkali becomes brown, gradually thickens, and at last forms a hard brittle mass. This arsenical salt of Mr. Macquer is deliquescent. It is soluble in water, which lets fall brown flocks. It is decomposed by fire, and the arsenic escapes. Acids deprive it of its alkali, &c.

Soda exhibits phenomena nearly similar with this oxide; and Mr. Macquer even affirms that he obtained this salt in crystals.

I have proved that ammoniac dissolves the oxide of arsenic by heat; and I have several times obtained crystals of arsenic by spontaneous evaporation. I am even of opinion that the alkali is decomposed in these circumstances, that the nitrogene is dissipated, while the hydrogen unites with the oxygen of the oxide, and forms water.

The oxide of arsenic hastens the vitrification of all the earths; but the glasses into which it enters as a component part, have the property of easily becoming tarnished.

Equal parts of nitre and oxide of arsenic, distilled in a retort, afford a very red and almost incoercible nitric acid. Stahl and Kunckel obtained it by a process nearly similar. Macquer having resumed this work, carefully examined the residue in the retort, and found that it was a salt soluble in water, capable of crystallizing in tetrahedral prisms terminated by four-sided pyramids, unalterable in the air, fusible by a moderate heat, but without becoming alkalized. Mr. Macquer called it the neutral arsenical salt: he supposed that no acid could decompose it. But Mr. Pelletier proved that the sulphuric, when distilled with it, disengaged its acid.

The arseniate of soda differs little from the arseniate of pot-ash. Mr. Pelletier obtained this salt crystallized in hexahedral prisms, terminated by planes perpendicular to their axes.

By these several experiments, Mr. Macquer had shewn that arsenic answered the purpose of an acid in these combinations. There remained only one step therefore to be made, to prove that it was really metamorphosed into an acid in these several operations: and it is to the celebrated Scheele that we are indebted for this discovery. His capital experiments upon manganese naturally led him to it.

He has given us two processes to obtain this arsenical acid; the first by means of the oxygenated muriatic acid, and the other by the nitric acid. These acids are distilled from the oxide of arsenic: the muriatic acid abandons its oxygen to the oxide of arsenic, and resumes the characters of the ordinary muriatic acid. The nitric acid is itself decomposed; and one of its principles is dissipated, while the other is fixed and combines with the arsenical oxide.

This acid is at present obtained by distilling six parts of nitric acid from one of oxide of arsenic.

Mr. Pelletier likewise proposes to decompose the nitrate of ammoniac by the oxide of arsenic. The residue in the retort is the arseniate of ammoniac, from which the alkali may be driven by a fire long kept up. The residue is a vitreous mass, strongly attracting humidity, and falling into deliquium. It is the pure arsenical acid.

Mr. Pelletier has likewise decomposed the neutral arsenical salt, by mixing it with half a part of oil of vitriol, and urging the fire to such a degree as to ignite the vessels. The residue at the bottom of the retort is a white mass, which attracts humidity, and is the arsenical acid. A white powder is observable, which is found to be the sulphate of pot-ash or of soda, accordingly as the arsenical salt has soda or pot-ash for its basis.

From the various processes made use of to form the arsenical acid, it is evident that this substance is nothing but the arsenical oxide, saturated with the oxigene which it takes from the various bodies digested upon it. The nitric acid, or the nitrates used for this purpose, are decomposed; the nitrous gas passes over very abundantly, and the oxigene remains mixed and united with the oxide of arsenic.

This acid possesses the concrete form; but it attracts the humidity of the air, and becomes resolved into a fluid.

It is fixed in the fire; but if it be heated in contact with a coaly substance, it is decomposed, and the oxide exhales in the form of fumes. It is reduced into arsenic, according to Mr. Pelletier, by passing hydrogenous gas through it.

At the temperature of twelve degrees of the thermometer of Reaumur, this acid requires only two-thirds of its weight of water to dissolve it; whereas one part of the oxide of arsenic requires twenty-four of water to dissolve it at the same temperature.

This acid, when dissolved in water may be again concentrated, and carried to the state of a transparent glass without any alteration; for it is not by this treatment deprived of its power of attracting humidity from the air.

When it is in this state of concentration, it acts strongly on the crucible, and dissolves the alumine, according to Mr. Berthollet's experiments.

The arsenical acid, saturated with ammoniac, and duly evaporated, forms a salt crystallized in rhomboides; which, when urged by heat, loses its water of crystallization, next its alkali, and is resolved into a vitreous mass.

Barytes and magnesia appear likewise to have a stronger affinity with this acid than the alkalis, according to Bergmann. Lime decomposes the neutral salts with base of alkali, according to the experiments of the same chemist.

Arsenic is used by the dyers; it is likewise used as a flux in glass-houses, and in docimastic works; it also enters as a component part into some glazes. Orpiment and realgar are very much used by painters; but arsenic is one of those productions whose advantages are not sufficient to compensate for its bad effects. This metal, which is very abundant, and very frequently met with in mines, causes the destruction of a number of workmen who explore them: being very volatile, it forms a dust which affects and destroys the lungs; and the unhappy miners, after a languishing life of a few years, all perish, sooner or later. The property which it possesses of being soluble in water, multiplies and facilitates its destructive power; and it ought to be proscribed in commerce, by the strict law which prohibits the sale of poison to unknown persons. Arsenic is every day the instrument by which victims are sacrificed, either by the hand of wickedness or imprudence. It is often mistaken for sugar; and these mistakes are attended with the most dreadful consequences. Whenever there is the least reason to suspect its presence, the doubt may be cleared up by throwing a small quantity of the powder upon heated coals. The smell of garlic, and the white fumes, are indications of the presence of arsenic. The symptoms which characterize this poison are, a great constriction of the throat, the teeth set on edge, and the mouth strongly heated; an involuntary spitting, with extreme pains in the stomach; vomiting of glairous and bloody matter, with cold sweats and convulsions.

Mucilaginous drinks have been long ago given to persons poisoned by arsenic. Milk, fat oils, butter, &c. have been successively employed.—Mr. Navier has proposed a more direct counterpoison. He prescribes one dram (gros) of sulphure of pot-ash, or liver of sulphur, to be dissolved in a pint of water, which the patient is directed to drink at several draughts: the sulphure unites to the arsenic, and destroys its causticity and effect. When these first symptoms are dissipated, he advises the use of mineral sulphureous waters. He likewise approves of milk, but condemns the use of oils. Vinegar, which dissolves arsenic, has been likewise recommended by Mr. Sage.



## CHAPTER II.

*Concerning Cobalt.*

**COBALT** was employed by artists to give a blue colour to glass, long before it was supposed to contain a semi-metal. We are indebted to Brandt, a celebrated Swedish mineralogist, for the knowledge of its properties, and metallic character.

The specific gravity of fused cobalt is 78119. See Briffon.

Cobalt is combined in the bowels of the earth with sulphur, arsenic, and other metallic substances.

1. The arsenical cobalt ore is of a grey colour more or less deep, dull in its fracture, and becoming black on exposure to the air; in consequence of an alteration in its arsenical part.

This ore of cobalt crystallizes in smooth cubes, and affects several varieties. I have a piece which has the form of tetrahedral pyramids, joined base to base. This species of cobalt sometimes affects a confused crystallization in dendrites, and is then called Knit-cobalt ore. Sometimes it is found in protuberances, stalactites, &c.

2. The sulphureous ore of cobalt resembles the grey silver ore in its texture: it contains iron and silver; and effloresces of a lilac colour, mixed with a yellowish green. —Sage, *Annal. Chem.* t. ii.

Mr. De Lisle possesses specimens of this kind, which came from the mine of Batnaes at Riddarhyttan.

3. Cobalt is mineralized by sulphur and arsenic, in the mine of Tunaburg in Sudermania.

The crystallization of this species is a cube striated on its six faces, and commonly truncated more or less deeply on its edges.

This ore contains, according to Mr. Sage, fifty-five pounds of arsenic, eight of sulphur, two of iron, and thirty-five of cobalt.

4. The ores of cobalt are sometimes in efflorescence; and the sulphureous ore forms by its decomposition the sulphate of cobalt.

The sulphure of cobalt, and the arsenical cobalt ore, pass to the state of oxide in their decomposition; and the surface becomes covered with a colour of peach flowers, more or less intense. It is sometimes coloured with an efflorescence in the figure of stars formed by radii applied to each other collaterally, and all tending to a common centre. This is an indistinct crystallization, in which Mr. De Lisle thinks he observed tetrahedral prisms terminated by dihedral summits. The flowers of cobalt are frequently a mere powder, more or less coloured. Those ores which are in a state of complete decomposition are called Soft or Earthy cobalt ores.

To assay an ore of cobalt, the first process is torrefaction. Two hundred grains are afterwards fused with an ounce and a half of black flux. Mr. Sage is confident that more metal is obtained by mixing the oxide of cobalt with two parts of white glass, and a small quantity of coal.

When cobalt is mixed with bismuth and iron, its oxide must be distilled with equal parts of the muriate of ammoniac, until the salt which sublimes in the neck of the retort has acquired a green tinge. Mr. Sage, who gives us this process, observes that seven or eight sublimations are sometimes necessary to deprive the cobalt of all the iron and bismuth which it contains.

Cobalt is of a light grey colour, compact and brittle. It is not easily fused, is not volatile, resists cupellation, and refuses to amalgamate with mercury.

The working of cobalt ores is very simple. It consists in roasting the ore in a reverberatory furnace terminating in a long chimney, into which the vapours are received. These vapours, or arsenical fumes, attach themselves to the sides, and form a crust, which is cleared off by criminals, who are condemned to this work for crimes that by the law deserve death. The cobalt ores of Saxony afford all the arsenic of commerce. When the oxide of cobalt is cleared of arsenic, it is known by the name of Zaffer. The zaffer of commerce is mixed with three-fourths of sand. This oxide, fused with three parts of sand, and one of pot-ash, forms a blue glass, which, when pounded, sifted, and afterwards ground in mills, included in large casks, forms

Smalt. In order to obtain the blue of various degrees of fineness, the smalt is agitated in casks filled with water, and pierced with three openings at different heights. The water of the upper cock carries out the lightest blue, which is called Azure of the First Fire: the heavier particles fall more speedily; and the azure brought out by the water of the three cocks, forms the different degrees of fineness known under the names of Azure of the First, Second, and Third Fire.

Bohemia and Saxony have hitherto possessed the exclusive power of supplying us with these products. A description of these capital works may be seen in the mineralogical productions of Messrs. Jars. The works of Saxony have been supplied, for several years, by the cobalt ore discovered in the Pyrenean Mountains, in the valley of Gisten. But the Comte de Beust has formed establishments which secure to us the benefit of this commerce; and he has even been so fortunate as to find, near the village of Juget, a quartz sufficiently charged with cobalt to admit of being fused without any addition of colouring matter.

The establishment of the Comte de Beust is capable of manufacturing six thousand quintals of azure, or enamel blue; and is able not only to supply our own wants, but to enter into competition with the works of Saxony for the foreign trade\*.

He has likewise, in concert with the Baron Dietrich, discovered the process of making powder blue; a secret which was exclusively in the possession of the Hollanders till the present time.

Smalts are used in the preparation of cloths, laces, linens, muslins, thread, &c.

The azures are mixed with starch, and form the blue so well known and universally used by laundresses.

It is likewise employed in forming blue paintings on fayence, porcelain, and other potteries; crystals and glasses are coloured blue by this substance; and it is also used in painting in fresco.

\* A description of the works of the Comte de Beust may be seen in the *Description des Gites des Minerais, des Forges, et des Salins des Pyrénées*, par M. le Baron de Dietrich.

The coarsest blues are used by the confectioners and others, in the way of ornament; and in Germany they are used as sand for writing-paper.

The consumption of smalt, azure, blue sands, and zaffers, in the kingdom of France only, is estimated at four thousand quintals, which are sold from seventy-two to six hundred livres the quintal.

Cobalt is soluble in the acids.

One part of this metal, distilled with four parts of sulphuric acid, affords the sulphureous acid; and the residue in the retort is the sulphate of cobalt, soluble in water, and capable of crystallizing in tetrahedral rhomboidal crystals, terminating in a dihedral summit.

Barytes, magnesia, lime, and alkalis decompose this salt, and precipitate the cobalt in the form of oxide.

One hundred grains of cobalt dissolved in the sulphuric acid, and precipitated by soda, afford one hundred and forty grains of precipitate, and one hundred and sixty when precipitated by chalk.

The nitric acid dissolves cobalt with effervescence. The solution affords crystals in needles, which have not been strictly examined. This salt is deliquescent, boils on the coals without detonating, and leaves a deep red calx. I have seen this salt in very short beautiful hexahedral pyramids. It decrepitates and fuses on charcoal.

The muriatic acid does not dissolve cobalt in the cold, but by the assistance of heat it dissolves a portion of it. This acid acts more effectually upon the zaffer, and the solution is of a very fine green, and when diluted with water constitutes a very singular sympathetic ink; for it passes from a lilac, or violet colour, to purple, green, and black.

The nitro-muriatic acid likewise dissolves cobalt, and forms the sympathetic ink, which Hellot has called the Ink of Bismuth.

Ammoniac likewise dissolves zaffer, and produces a liquor of a beautiful red colour.



## CHAPTER III.

*Concerning Nickel.*

**H**YERNE appears to have been the first who treated of nickel, under the name of Kupfernicksel, in 1794, in a work on minerals.

Henckel considered it as a species of cobalt, or arsenic mixed with copper.

Cramer has likewise placed it among the ores of copper ; and it was not until the year 1751, that Cronstedt obtained a new semi-metal from this pretended mixture.

Kupfernicksel is found not only in the German districts, but likewise in Dauphiny, and in the Pyrenean Mountains. In digging out a calcareous stone for building, at Bareges, and opposite St. Sauveur, small veins and lumps of nickel were found in the calcareous spar, some parts of which were reduced to the state of green oxide. Mr. Sage, who analysed that of Biber in Hesse, and that of Allemont, found it to contain gold.

In order to obtain nickel from its ore, it must first be torrefied to disengage the arsenic ; and the oxide must then be fused with three parts of black flux, and a small quantity of coal. This metal is of a reddish grey colour.

The specific gravity of fused nickel is 7,8070. Brisson.

As it is very difficult to drive off all the the arsenic by a previous torrefaction, the metal, when urged by a violent fire, still suffers arsenic to escape.

The methods pointed out by Bergmann and Arvidson to purify nickel, consist in repeated calcinations and reductions : but these operations separate the arsenic only ; and Bergmann admits that he did not succeed in completely depriving it of its iron, though he treated it by every suitable method. He seems disposed to consider it as a modification of iron.

The Dissertation of Bergmann De Nicolo, Opuscula, t. ii. may be consulted on the nature of this metal ; and also the Analyse Chimique of Mr. Sage, &c.

The sulphuric acid distilled upon nickel affords sulphureous acid, and leaves a greyish residue, which, when dissolved in water, communicates to it a green colour.

The sulphate of nickel effloresces in the air.

Nickel is attacked very strongly by the nitric acid.

The solution, when evaporated, affords crystals of a beautiful green, in rhomboidal cubes.

The nitric acid likewise dissolves the oxide of nickel, and forms with it deliquescent crystals of a fine emerald green, and of a rhomboidal form, according to Bergmann.

The muriatic acid dissolves nickel, when heated. The solution produces crystals of the most beautiful emerald green, and of the figure of long rhomboidal octahedrons.

Cronstedt has taught us that nickel combines with sulphur by fusion, and that the result is a hard yellow mineral, with small brilliant facets. The same chemist dissolved this last metal in the sulphure of pot-ash, and formed a compound resembling the yellow copper ores.

Nickel does not amalgamate with mercury.

## CHAPTER IV.

### *Concerning Bismuth.*

**BISMUTH**, or tin-glass, is a semi-metal of a shining yellowish white, disposed in plates and chatoyant. It has some analogy with lead; and, like that metal, it passes off on the cupel, carrying the baser metals along with it.

The specific gravity of fused bismuth is 9,8227.—See Briffon.

Bismuth is the most easily fused of all the semi-metals, after tin. It requires only the 200th degree of heat.

It is found in various states in the bowels of the earth, either native, or combined with sulphur, arsenic, or oxigene.

1. Native bismuth is sometimes crystallized in cubes: Wallerius and Cronstedt found it in this form in the mines

of Schneeberg in Saxony. These crystals often re-unite in the form of dendrites, in the spathose or quartzose gangues. Native bismuth is found in masses, covered with protuberances resembling stalactites.

Native bismuth is frequently altered by a slight decomposition of its metallic surface.

The native bismuth of Saxony is sometimes irised, and mixed with arsenic: it has a reddish jasper for its gangue.

2. Arsenical bismuth is of a whitish and brilliant grey colour. This ore is sometimes covered with an ochre of bismuth, and often contains cobalt. I have seen pieces of arsenical bismuth, from Schneeberg, in the form of dendrites on a gangue of jasper.

3. We are indebted to Mr. Cronstedt for the knowledge of a sulphureous ore of bismuth. That which he has described is of a blueish brilliant grey colour.

This species frequently possesses the lamellated texture of the large plated galena, which has caused Linnæus, Wallerius, and others, to give it the name of Galena of Bismuth. It is found at Batneas, at Riddarrhitan in Westmanland. It decrepitates on heated coals, and requires to be pulverized, in order to torrefy it without loss.

The galena of bismuth is sometimes striated.

The sulphureous ore of bismuth is sometimes compact, of an obscure colour, sprinkled with small brilliant points. That of Schneeberg in Saxony is of this kind.

Mr. De la Peyrouse discovered, in 1773, on the mountains of Melles in Cominges, in the quarter called Les Raitz, an ore of bismuth, which resembles this small plated galena, and has no external difference, excepting that it is less heavy. This ore is mineralized by sulphur, in the proportion of thirty-five livres per quintal.

4. Cronstedt, Linnæus, Justi, and De Born, have spoken of a bismuth ore of a greenish yellow, found in Saxony, and in Sweden. Mr. Sage communicated to the Academy, on the 17th of August, 1780, the analysis of an earthy, solid, yellowish green ore of bismuth. He obtained quartz in the proportion of one-third, some carbonic acid, thirty-six pounds of bismuth per quintal, and twenty-four grains of silver: he found neither copper nor iron. Besides this green ore, he analysed a yellow, solid, slightly

brilliant, and sometimes semi-transparent ore, which afforded him nearly the same results, but nine pounds more of bismuth.

This oxide must be fused in the blast furnace.

The fusibility of bismuth renders the working of this ore very simple, and the apparatus may be varied in several ways. Nothing more is necessary than to throw the ore into the fire, and to make a cavity underneath to receive the semi-metal.

Bismuth, when heated to redness, burns with a blue flame, scarcely perceptible. Its oxide rises in the form of a yellowish fume, which, when condensed, forms the flowers of bismuth. Its weight is increased twelve per cent. in passing to the state of oxide.

Mr. Darcet has converted bismuth into a glass of a dull violet colour.

Bismuth may be substituted instead of lead, in the process of cupellation. Its vitrification is even more speedy.

The sulphuric acid, boiled on bismuth, suffers sulphureous acid to escape, and partly dissolves the semi-metal. The sulphate of bismuth does not crystallize, but is very deliquescent.

The nitric acid attacks bismuth, and is very speedily decomposed. Nitrous gas is disengaged, while the oxigene is fixed in combination with the metal. There is nevertheless a portion dissolved which is capable of forming a salt in rhomboidal, tetrahedral prisms, terminating in a tetrahedral pyramid with unequal faces. This nitre detonates weakly with reddish scintillations; and melts, swells up, and leaves an oxide of a greenish yellow colour.

This salt loses its transparency in the air, at the same time that its water of crystallization flies off.

The muriatic acid does not act on bismuth but in the course of a considerable time; and for this purpose it must be highly concentrated. The muriate of bismuth is of difficult crystallization, and strongly attracts the humidity of the air.

Water precipitates this semi-metal from all its solutions; and the precipitate, when well washed, is known by the name of Magistery of Bismuth, or white paint for the complexion. This white is used as a pigment for the skin;



but strong or sulphureous vapours, and even the animal transpiration, convert it into metal, and alter its colours. The hair-dressers, when they are desirous of converting hair to a black colour, smear it with permatum prepared with the magistery of bismuth.

Bismuth is used by the pewterers to give hardness to the metallic composition of pewter.

Mr. Pott has published a dissertation, in which he affirms that physicians have made use of some preparations of this semi-metal: but it is proper that it should be prohibited, because it almost always retains a portion of arsenic, and it self partakes of the noxious properties of lead.

The white of bismuth is very much used as a paint for the complexion. Its various solutions form sympathetic inks, which are more or less curious, on account of the facility with which this oxide is altered, and becomes black.

Schluter, in his Treatise of the Fusion of Ores, pretends that it may be used in making the azure blue glafs. But it appears, from his own account, that he made use of a bismuth ore very rich in cobalt. For he says, that a moderate fire causes this ore to suffer its bismuth to flow out, and that residue is a grey and fixed earth, which may be employed to advantage in making the blue.

This semi-metal unites with all the metals; but very difficultly, in the way of fusion, with the other semi-metals, or the metallic oxides. Antimony, zinc, cobalt, and arsenic refuse this union.

Bismuth, fused with gold, renders it eager, and communicates to it its own colour. It does not render silver so brittle as gold: it diminishes the red colour of copper, but is deprived of its own colour by uniting with lead; the two metals, in this case, forming an alloy of a dark grey colour. When bismuth is mixed in a small proportion with tin, it gives it a greater degree of brilliancy and hardness. It may be united with iron by a violent heat.

Bismuth amalgamates with mercury, and forms a fluid alloy; a circumstance which has induced certain unprincipled druggists to mix it with that metal. The fraud may be known from the mercury being less fluid than before, and no other test is necessary than to dissolve the mixture in

spirit of nitre; for the bismuth will be precipitated by the addition of water.

This property, however, of amalgamating completely with mercury, may cause it to be applied with advantage in the silvering of glasses, by an amalgam of tin, bismuth, and mercury. This is, perhaps, the circumstance which has obtained it the name of tin-glass.

The fusible alloy of Mr. Darcet is a mixture of eight parts of bismuth, five of lead, and three of tin. It melts in water at the seventy-third degree of Reaumur, and flows like mercury.

## CHAPTER V.

### *Concerning Antimony.*

**ANTIMONY** is a semi-metal which has singularly engaged the attention of alchemists. They considered it as the basis of their great work; and it is described in their writings under the names of the Radical Principle of Metals, Sacred Lead, &c.

This semi-metal is famous for the disputes which were maintained concerning it, at the beginning of the sixteenth century. It was prohibited by a decree of parliament, at the solicitation of the faculty of Paris. Poumier of Caen, a skilful physician and chemist, was degraded by the Faculty of Medicine, for having employed it in 1609.

This same proscribed metal was re-established in 1624; and at present affords the most powerful remedies possessed by the medical art.

Bazilius Valentinus, a zealous partizan of antimony, pleaded its cause with much warmth and enthusiasm, in a work entitled *Currus Triumphalis Antimonii*: and Lermery has written a large volume to decry the preparations of this semi-metal.

As this substance afforded employment for a long time to the alchemists, its study is rendered particularly difficult by the multiplicity of preparations, and the barbarous names

which have been given to them, and to the variety of processes. But by confounding preparations of the same nature; by bringing the analogous products together, rejecting at the same time the numerous list of barbarous names which have been bestowed on one and the same thing; and by reducing the processes to that simplicity of which the well-known preparations are susceptible; we may succeed in forming an accurate and precise idea of the nature and properties of this metal.

Antimony is found in the bowels of the earth, in four different states.

1. In the metallic form.
2. Combined with arsenic.
3. Mineralized with sulphur.
4. In the state of oxide.

1. Some authors pretend that antimony in the metallic state was discovered in the year 1748, by Ant. Swab, in the mine of Sahlburg, in Sweden. Swab affirms that it has the colour of silver, that its texture is formed of large brilliant plates, and that it easily amalgamates with mercury. Cronstedt, Wallerius, Linnæus, and Cartheuser, do not hesitate to admit of native antimony; but Lehman, Justi, and Vogel deny its existence: and Mr. De Lisle thinks that this pretended regulus is nothing but the white arsenical ore of antimony. The abbé Mongez affirms that he has discovered native antimony at Allemont in Dauphiny. It is the same ore which Mr. Sage has described under the name of the Arsenical Ore of Antimony.

If this native Antimony really exists, it is probably crystallized like the metal itself, which is known to us, and whose crystals are either octahedrons inserted one in the other, or cubes placed one upon each other slantwise.

2. The arsenical ore of antimony may be considered as a true regulus by those who, after Bergmann, do not admit of arsenic as a mineralizer: for the ore is then considered as an alloy of the two reguli.

This ore is as white as silver, and exhibits large facets like antimony. The specimen was sent from Allemont in Dauphiny, to Mr. Sage. Its gangue is quartz. Small fasses of the grey and red ores of antimony striated and radiated, and not containing arsenic, are sometimes found in the cavities of this stone.



The antimony and the arsenic exist in the metallic state in this ore. The arsenic adheres so strongly to the antimony that it cannot be disengaged by torrefaction. Mr. Sage combined the ore with sulphur, and obtained orpiment and realgar. This mineralogist has concluded, from his analyses, that the arsenic existed in the proportion of sixteen pounds in the hundred.

3. Antimony is usually mineralized by sulphur, in which combination it exhibits three or four very distinct varieties. It is sometimes crystallized of a grey colour inclining to blue. The crystals are very frequently slender, oblong, hexahedral prisms, terminated by tetrahedral pyramids. The mines which are wrought in Auvergne afford us beautiful prisms, of the same geometrical form, but thicker than those of the antimony of Hungary. These last crystals soon become of an irised colour; but those of the mines of Auvergne are not so speedily changed. I possess a large specimen of antimony from the neighbourhood of Alais, which is entirely covered with crystals perfectly similar to those of Hungary. It frequently happens that these crystals are confused and indistinct, in which case the ore appears to be formed of very slender prisms applied sidewise to each other. That which is called plumose antimony does not differ from these varieties, excepting that its crystals are very slender and detached. They are usually of a blackish grey. This variety has been arranged among the ores of silver, because for the most part it contains that metal.

Ores of antimony have been found in several parts of France; but our province of Languedoc exhibits very curious specimens. We have them at Malbos in the county of Alais. This mineral has been wrought in the diocese of Uzès; but the want of consumption has prevented the works from going on with spirit. Mr. De Genstane has observed in Vivarais a large vein of ore of antimony in a stratum of pit-coal.

The decomposition of the sulphureous ore of antimony produces the red antimonial ore. The red ore more especially accompanies the specular antimony of Tuscany. Its surfaces appear to be corroded or rendered carious by decomposition; and when a piece is broken, it emits a powder which has the properties of kermes.



The decomposition of sulphureous antimony likewise produces the sulphate of antimony. Some varieties of these antimonial decompositions may likewise be seen in the *Analyse Chimique* of Mr. Sage.

Antimony is found in two states in the course of trade; namely, in the form of crude antimony, and in the metallic form.

Crude antimony is nothing else but the sulphureous ore of antimony cleared of its gangue. For this purpose the ore is put into pots pierced at the bottom, and disposed upon other pots buried in the earth. The uppermost pots which contain the mineral are then heated; the antimony becomes fused, and flows, together with its sulphur, into the lower vessels, while the gangue remains in the upper pots.

As the mixture of antimony, and sulphur is very fusible, this process may be varied in a thousand ways. I have myself wrought an antimonial ore with the greatest economy, by fusing it in a furnace, over the arch of which I had disposed the ore broken into pieces of five or six pounds weight each. The heat was communicated to the whole mass by five openings in the arch or roof; and the antimony, as it melted, ran down on the outside of the furnace by means of channels cut in the convex part of the dome. This method afforded forty quintals of antimony in twenty-seven hours, by the consumption of between twenty and thirty quintals of combustible matter.

We are acquainted with two methods of depriving crude antimony of its sulphur. 1. The slow and gradual calcination of the ore, which affords a grey oxide, and this urged by a violent heat is converted into a reddish and partly transparent glass of antimony. It does not assume this transparence unless it has been perfectly fused. The glass of antimony is a violent corrosive, but is capable of being corrected by mixing or kneading it with yellow wax, and afterwards burning of the wax; or otherwise by triturating it with a volatile oil. This is the cerated antimony of Pringle, so much extolled in dysenteries. 2. Or otherwise, the antimony may be deprived of its sulphur by projecting into an ignited crucible a mixture of eight parts of crude antimony, six of tartar, and three of nitre. By

keeping this mixture for a certain time in fusion, the antimony is obtained in the metallic state.

In the large works antimony is torrefied in an oven resembling that of the bakers. Fifty pounds of dried wine lees or tartar are mixed with a hundred pounds of the oxide of antimony, and the mixture is then fused in proper crucibles. The metallic button contains the form of the crucible; and these loaves of antimony exhibit a star on their upper surface, which has been considered as peculiarly characteristic; but is in fact nothing more than a confused crystallization formed by octahedrons inserted one in the other.

Copper, silver, and iron, when fused with the sulphure of antimony, seize its sulphur, and reduce it to the state of regulus. This has been distinguished by the name of the metal employed. Thus we hear of the regulus of Mars, of Venus, &c.

Antimony is difficult of fusion; but when once melted, it emits a white fume known by the name of Argentine Snow, or Flowers of Antimony. These fumes, when collected, form very brilliant prismatic tetrahedral crystals: Mr. Pelletier has obtained them in transparent octahedrons. The argentine flowers of antimony are soluble in water, which they render emetic. The volatility and solubility of this sublimed oxide exhibit a resemblance with the oxide of arsenic before treated of. We are indebted to Rouelle for these observations on the properties of this antimonial oxide.

Antimony is very slightly changed by exposure to air, in which it long preserves its brilliancy.

The specific gravity of fused antimony is 6,7021.—See Briffon.

The sulphuric acid, by slow ebullition upon this metal, is partly decomposed. Sulphureous gas first escapes, and sulphur itself is sublimed towards the end. When four parts of the acid are used with one of the antimony, the residue, after the action of the acid, consists of the metallic oxide, with a small quantity of the sulphate of antimony, which may be separated by means of distilled water. This sulphate is very deliquescent, and is easily decomposed in the fire.

The nitric acid is decomposed upon this semi-metal with great facility. It oxidizes a considerable part, and dissolves a portion, which may be suspended in water, and forms a very deliquescent salt, decomposable by heat. The oxide prepared by this means is very white, and very difficult of reduction. It is a true bezoar mineral.

The muriatic acid acts upon antimony only by a long digestion. Mr. Fourcroy has observed that this acid, long digested upon the metal, dissolves it; and that the muriate of antimony, obtained by a strong evaporation in the form of small needles, is very deliquescent. It is fusible in the fire, and likewise volatile. Mr. Monnet has proved that twelve grains of the oxide of antimony are sufficient to saturate half an ounce of the ordinary muriatic acid. Messrs. Monnet and De Fourcroy have always found that there is a portion of the muriate of antimony which is not volatilized by the fire: this depends upon its being strongly oxidized or calcined.

If two parts of the corrosive muriate of mercury, and one of antimony, be distilled together, a very slight degree of heat drives over a butyraceous matter, which is called butter of antimony, or the sublimed muriate of antimony. It may be presumed that the acid in this composition is in the state of oxygenated muriatic acid, as it is in the corrosive sublimate.

The sublimed muriate of antimony becomes fluid by a very gentle heat; and by virtue of this property it may conveniently be poured from one vessel to another: for nothing more is necessary than to plunge the bottle which contains it into hot water, and the muriate may then be poured out in its liquid state.

I have several times observed this muriate of antimony crystallized in hexahedral prisms with dihedral summits: two sides of the prism are inclined, and form that which the ancient chemists distinguished by the name of crystals in the form of a tomb. This muriate is used as an escharotic. When the salt is diluted with water, a white powder falls down, called powder of algaroth, or *mercurius vitæ*. This powder does not contain an atom of the muriatic acid, and is merely an oxide of antimony produced by that acid.



Simple water has some action upon this semi-metal; for we find that it becomes purgative by remaining in contact with it. Wine, and the acetous acid, completely dissolve it: but the emetic wine is an uncertain remedy; because it is impossible to determine with absolute certainty the degree of its energy, which depends upon the very variable degree of acidity of the wine made use of. The emetic wine ought not therefore to be used but in external applications.

The gastric fluids likewise dissolve this semi-metal, as is proved by the famous perpetual pills. This purgative has been distinguished by the name of Perpetual Pills; because, being very little alterable, the pill may be transmitted from generation to generation.

The acid of tartar forms a very well known salt with antimony, which is much employed in medicine under the name of Emetic Tartar, Stibiated Tartar, or simply Emetic. It is this salt which, in the New Nomenclature, is distinguished by the name of Antimoniated Tartrate of Pot-ash.

In the examination of the various authors who have treated of the preparations of this remedy, as well as by comparing the most celebrated dispensatories, we do not find two which propose an uniform process which is constant and invariable in its effects.

Some prescribe the crocus metallorum, or semi-vitreous oxide of sulphurated antimony; others the glass of antimony; others the liver of antimony, or sulphurated oxide of antimony; and others the sublimed oxide: some combine several of these substances. But all in general adopt cream of tartar, or the acidulous tartrate of pot-ash, as a solvent.

The processes vary not only in the choice of the substances to be made use of, but even in the proportions in which they are to be employed. We likewise find varieties in the quantity of water used as a vehicle, which is not an indifferent circumstance; in the time prescribed to digest the substances together, a circumstance of the greatest consequence to be ascertained, because the saturation of the acid depends absolutely and essentially upon it. The choice of vessels must likewise influence the effect of this remedy. Hoffmann has affirmed that the emetic lost its effect by a long ebullition; and Mr. Baumé has proved that iron precipitates the antimony after a time, and consequently that the iron



vessels prescribed in certain dispensatories ought to be rejected.

This variety in the processes must necessarily influence the result ; and we cannot be much surprised that Geoffroy, who analysed several antimoniated tartrites of pot-ash, should have found from thirty grains to two gros and ten grains of metal in the ounce of this salt.

Is it not therefore of great consequence to prescribe a uniform process, whose product should be invariable ? These heroic remedies, which operate in small doses, ought to produce constant and invariable effects through all Europe. It would be much more advantageous that solemn proceedings should be made for the preparation of these active remedies, than for the composition of the theriaca, a true pharmaceutic monster, the dose of which may with impunity be varied from a few grains up to three hundred. It follows, from the variety of the effects of these sovereign remedies, that consultations become almost ineffectual ; because the physician prescribes according to the effects of the remedies he is in the habit of using : and the art of medicine becomes no better than a discouraging alternative of success and disappointment.

At Montpellier, the emetic acts in a dose of one or two grains ; but in other places it does not operate in a less dose than ten or twelve : and the stibiated tartar sold by those wholesale dealers in medicine, who supply the country apothecaries, is usually nothing but the sulphate of pot-ash, or vitriolated tartar moistened with a solution of emetic. It is a thing greatly to be desired, that government, which does not apply its stamp of approbation to objects of luxury until they have passed a rigid inspection, should prohibit traders from circulating with impunity, products upon which the health of the citizen so essentially depends. These are the frauds and deceptions which have engaged me to form an establishment of chemical products, in which intelligence and probity preside over all its operations ; and I have succeeded in my laboratories so far as to conduct the processes with sufficient œconomy to afford products faithfully made up, and invariable in their effects, at the same price as those sophisticated drugs with which the public has hitherto been poisoned.

The most accurate process for making an excellent emetic consists in taking very transparent glass of antimony, grinding it fine, and boiling it in water, with an equal weight of cream of tartar, until this salt is saturated. By filtration, and evaporation with a gentle heat, and subsequent repose, crystals of the antimoniated tartrate of pot-ash are obtained, whose degree of emeticity appears to be sufficiently constant. The crystals may be obtained in several successive products by repeated evaporations.

Macquer proposed the powder of algaroth, as more uniform in its power. Messrs. De Lussane and Durande have adopted the opinion of Macquer; and the celebrated Bergmann has followed the ideas of the French chemists, with a few slight modifications.

Take five ounces of cream of tartar reduced into powder, and two ounces two gros of the powder of algaroth precipitated by hot water, washed and dried. Add water to these, and boil them gently. By filtration and evaporation the crystals of emetic tartar are obtained; which may be given in the dose of three grains, without fatiguing the stomach or intestines.

The antimoniated tartrate of pot-ash crystallizes in trihedral pyramids. It is very transparent, is decomposed on the fire with crackling, and leaves a coaly residue. Sixty parts of water dissolve it. It effloresces in the air, and becomes farinaceous. The solutions of this salt throw down a mucilage, which fixes, and forms a pellicle of considerable thickness: it is the mucilage of cream of tartar, which is insoluble in water, and partly soluble in alcohol. The sulphuric acid blackens it, but does not itself become coloured till after a long time. The nitric acid dissolves it partly; and is itself decomposed, with the emission of much nitrous gas.

The alkalis and lime decompose the antimoniated tartrate of pot-ash. Antimony, properly mixed with the nitrate, decomposes that salt completely. Equal parts of the semi-metal and nitre being thrown into an ignited crucible, the salt detonates, its acid is decomposed; and at the end of the operation the crucible is found to contain the alkali which served as the base of the nitrate, and the antimony reduced to the state of white oxide: this is called

**Diaphoretic Antimony.** The same preparation may be made by using the sulphure of antimony; in which case three parts of the nitrate are used to one of the crude antimony. The residue in the crucible, after the detonation, is composed of the oxide of antimony, fixed alkali, a portion of the nitrate not decomposed, and a small quantity of sulphate of pot-ash. This compound is still known by the name of the Solvent of Rotrou. Water deprives it of all the salts it contains; and leaves only the oxide of antimony, which is called Washed Diaphoretic Antimony. If a small quantity of acid be poured on the fluid which holds the salts in solution, a small portion of the oxide of antimony falls down, which was dissolved by the alkali of the nitre. The precipitate forms the ceruse of antimony, or the pearly matter of Kerkringius.

Equal parts of the sulphure of antimony and of nitrate, detonated in an ignited crucible, form the liver of antimony or sulphurated oxide of antimony; which, when pulverized and washed, produces the saffron of metals, or *crocus metallorum*.

The oxides of antimony have been considered as very difficult of reduction; and it was not without surprize that I at first observed the facility with which they are all reducible by the black flux. This prejudice was established and propagated for want of proper experiments.

The alkalis do not sensibly act upon antimony: but the sulphures of alkali dissolve it completely; and it is upon this principle that an operation is founded by which we obtain a valuable remedy, known by the name of *Kermes Mineral*, to distinguish it from the vegetable kermes used in dying. The preparation is simply a red sulphurated oxide of antimony. This remedy, first pointed out by Glauber, who made it with antimony and the solution of nitre fixed by charcoal, is indebted for its celebrity to the wonderful cures it performed in the hands of Simon, a Chartreux friar; whence it obtained the name of the Powder of the Chartreux. This religious man obtained the composition from a surgeon named Laligerie, to whom it had been given by Mr. Chastenay, lieutenant at Landau. Mr. Dodart, first physician to the king, bought the secret in the year 1720; and Mr. Laligerie rendered it public.



According to his process, the pounded sulphure of antimony is boiled for two hours, with one fourth of its weight of the solution of fixed nitre or pot-ash, in twice its weight of very pure water. After ebullition the fluid is filtered; the kermes falls down as it cools, and is afterwards dried. Laligerie directs that more of the solution of fixed nitre be digested on the metal, till it is completely dissolved. Laligerie burned spirit of wine or brandy upon it. The liquor which remains after the kermes is fallen down, contains more kermes, which may be disengaged by means of an acid. This kermes, which is paler than the former, is known by the name of Golden Sulphur of Antimony, or or the orange-coloured sulphurated oxide of antimony.

This process is no longer used. That which succeeded the best with me, consists in boiling ten or twelve pounds of pure alkaline solution with two pounds of the sulphure of antimony. The ebullition is continued for half an hour, after which the fluid is filtered; and much kermes is obtained by mere cooling. I digest new alkali on the antimony, until it is consumed. The kermes which I obtain by this means is of a beautiful tufted appearance.

Geoffroy, who analysed the kermes in 1734 and 1735, found that one gros of kermes contained from sixteen to seventeen grains of antimony, from thirteen to fourteen grains of alkali, and from forty to forty-one of sulphur. But Messrs. Baumé, Deyeux, de la Rochefoucauld, and De Fourcroy, are not convinced that the washed kermes contains an atom of alkali which is not necessary to its virtues.

Kermes is likewise one of those remedies in the preparation of which the greatest care ought to be taken. It is nevertheless a substance which all the apothecaries in the country buy at the fair of Beaucaire; and the analysis which I have several times made of this kermes, has convinced me that it very often is nothing else but pounded brick, mixed with vegetable kermes, and sprinkled with a strong solution of emetic tartar. I have found some which was merely a mixture of the fine brown red and the calx of antimony.

Lime and lime-water, digested upon pulverized antimony, afford, even in the cold, at the end of a certain



time, a kind of kermes, or golden sulphur, of a beautiful red colour.

Antimony enters into the composition of printers types. It is likewise mixed with tin to increase its hardness. It was formerly used as a purgative: for this purpose it was made into cups, in which water or wine was suffered to stand for a night, and taken by the patient the following day.

The sulphure of antimony is used as a sudorific in skin disorders. For this purpose it is tied in a cloth, and digested in the ptisans appropriated to these disorders. It is administered in pills for the same purpose.

The solvent of Rotrou has been much used to dissipate lymphatic concretions, and pituitous swellings.

Washed diaphoretic antimony is used in considerable doses to excite perspiration. Some physicians have considered it as a medicine void of effect; and Boerhaave has maintained that its effect is not more considerable than that of Lemnian earth.

The kermes mineral is one of the most valuable medicines that the healing art is acquainted with. It is incisive; and may be administered in all pituitous cases, when the stomach fails, and the lungs are obstructed. In a more considerable dose it is sudorific, and a still larger portion is emetic. It is employed in the dose of from half a grain to three.

The tartar emetic has received its name from its uses. It is dissolved in water; and this solution produces its effect.

The liver of antimony, crude antimony, and the crocus metallorum, are more especially used as purgatives in the veterinarian practice. They are given to horses in the dose of about an ounce.

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## CHAPTER VI.

### *Concerning Zinc.*

**ZINC** is a metallic substance of a blueish brilliant white colour; very difficultly reducible into powder, but capable of being extended into very thin plates by the equal and gradual pressure of the flattening mill. From this last

property, which has been proved by Mr. Sage, we may consider zinc as the intermediate substance between semi-metals and metals.

Zinc is found naturally in various states.

1. Cronstedt affirms that he saw a radiated crystallization of a metallic appearance, which is found at Schneeberg, where it is called flowers of bismuth, but which he found to be the regulus of zinc. This celebrated mineralogist does not venture to pronounce that it is native zinc.

Mr. Bomare affirms that he found it in small pieces in the mines of lapis calaminaris in the duchy of Limbourg, and in the zinc mines of Goslar. This regulus may have arisen from the scorix of furnaces, or from the ancient works; so that the existence of native zinc is still considered as very doubtful by these mineralogists.

2. Zinc is usually mineralized by sulphur, forming an ore known by the name of Blende, which in German signifies *blinding* or *deceitful*; a name which may have been given to it because such districts as abound with this mineral are barren of other ores.

The determinate crystallization of blende appears to be the alumini-form octahedron, and sometimes the tetrahedron; but the modification of these primitive forms are so numerous, that the crystals are found in an astonishing variety of figures. Most commonly they are polyhedral crystals of an indeterminate form, or scarcely capable of being described. On this circumstance depend the denominations of Blende with Large or Small Plates, Striated Blende, Compact Blende, and other species, which may be seen in the works of Messrs. Sage, De Lisle, &c.

The colour of these blendes is infinitely various; they are found yellow, red, black, semi-transparent, &c.

All the blendes emit an hepatic smell when grated or triturated.

There is a kind of blende which exhibits a line of phosphoric flame when scratched with a knife, or even with a tooth-pick. Mr. De Bournon found this yellowish, transparent, and phosphoric blende, similar to that of Scharfsenburg, at Maronne in the mountains of Oisan, at the distance of nine leagues from Grenoble. The phosphoric blende contains scarcely any iron.

To make the affay of a blende, Mr. Monnet advises solution of the ore in aqua fortis. The acid unites with the metal, and separates the sulphur: after which the oxide of zinc may be obtained by distilling off the acid; and this may be reduced. Bergmann obtains one part of the sulphur of these ores by distillation, dissolves the residue in acids, and precipitates the metal from its solutions. Mr. Sage distils blende with three parts of sulphuric acid: the sulphur sublimes by this operation; and the residue in the retort is the sulphate of zinc, mixed with a small quantity of sulphate of iron, and other substances mixed with the zinc. I do not know any country where blende is wrought to obtain the zinc: but it is sometimes mixed with lead; and in the working of this last metal the former is occasionally obtained. Such is the ore worked at Rammelsburg near Goslar, in the lower Hartz. Great part of the zinc is dissipated during the fusion of the lead ore; but a portion of this metal is obtained by a very ingenious process. Care is taken to keep the anterior part of the furnace cool; against which a stone is placed with a slight degree of inclination. The vapours of the zinc which are carried against this stone, are condensed, and fall in drops into powder of charcoal; with which a stone placed at the bottom is covered. The semi-metal is defended from oxidation by means of the charcoal; and it is afterwards fused, and cast into convenient forms.

This zinc is always united with a small quantity of lead, and is less pure than that which comes to us from India, under the name of Tutenag.

I strongly calcined the blende of St. Sauveur, and mixed the powder with charcoal. I then put the whole into a retort whose orifice was plunged beneath water; and by a violent heat, kept up for two hours, I obtained much zinc, which fell to the bottom of the water.

3. The decomposition of blende gives rise to the formation of the sulphate of zinc. The operation of nature is slow, but art has supplied its defect. All the sulphate of zinc which is met with in commerce, is prepared at Rammelsburg. For this purpose, after having roasted the galena mixed with the blende, it is thrown ignited into cisterns full of water, where it is left for twenty-four hours. The



roasted mineral is three times extinguished in the same water; after which the lixivium is evaporated, and put into coolers. At the end of fifteen days the water is decanted, in order to separate the crystals of the sulphate of zinc. These crystals are afterwards fused in iron vessels; and the liquor is poured into coolers, where it is stirred till it congeals. We shall examine the properties of this salt in due course,

4. Zinc is likewise found in the state of oxide; and it appears to me that nature makes use of two means of converting the metal to this state. 1. The sulphur is sometimes dissipated without the production of sulphate: in which case it is replaced by the oxygenous gas, and the result is that oxide of zinc which is known by the name of *Lapis Calaminaris*. I have found strata of *lapis calaminaris*, at St. Sauveur, intermixed with layers of blende; and the transition of the blende to the state of *lapis calaminaris* may be followed in the most interesting manner. 2. The sulphate of zinc produced by the decomposition of blende in certain circumstances, is itself decomposed by calcareous stones. In the rich collections of Messrs. Sage, De Lisle, &c. we see crystals of calcareous spar converted into calamine at one end, and calcareous at the other.

Calamine crystallizes in rhomboidal tetrahedral prisms, or in hexahedral pyramids.

It is sometimes covered with protuberances; often has the appearance of being worm-eaten; and is, at other times, either spongy or compact.

Its colour varies greatly. The county of Somerset affords it of white, green, and other colours.

To make a good analysis of calamine, Bergmann advises solution in the sulphuric acid; he obtains the sulphates of iron and of zinc. That of iron is decomposed by a known weight of zinc; and the metal is afterwards precipitated by the carbonate of soda. He has ascertained that ninety-three grains of this precipitate are equivalent to one hundred grains of zinc; and from this weight he deducts that of the zinc made use of to precipitate the iron.

Zinc may be obtained from calamine by distillation. For this purpose I have used the same process as has already been mentioned in treating of blende.



Zinc yields beneath the hammer, without extending itself. If it be cast into small plates, it may then be laminated, and reduced into very thin and very flexible leaves.

The specific gravity of fused zinc is 7,1908. See Briffon.

Zinc, when heated, may be easily pulverized. This operation is very difficult without this precaution indicated by Maquer; for it wears and chocks up files, and destroys them in a short time: besides which, they have no considerable action upon it. It may likewise be fused and poured into water.—These are the most convenient means of pulverizing it.

Zinc, treated in close vessels, sublimes without decomposition: but when it is calcined in the open air, it becomes covered with a grey powder, which is a true oxide; and, if it be heated to redness, it takes fire, emits a blue flame; and white flocks issue from it, which are called Philosophical Wool, Pompholix, or Nihil Album. This oxide may be fused into glass by an exceedingly violent heat: the glass is of a beautiful yellow colour. Zinc laminated into very thin leaves, takes fire by the flame of a taper, and burns with a blue colour mixed with green.

Mr. De Laffone, who has written several excellent *Memoirs* on zinc, considers it as a kind of metallic phosphorus.

Water appears to have some action upon zinc. When this semi-metal begins to be ignited, if water be poured on it, the fluid is decomposed, and much hydrogenous gas is disengaged. Messrs. Lavoisier and Meusnier have ascertained this fact, in their fine experiments on the decomposition of water.

Sulphuric acid dissolves it in the cold, and produces much hydrogenous gas. A salt may be obtained by evaporation, in tetrahedral prismatic crystals, terminated by a four-sided pyramid. Mr. Bucquet has observed that these prisms are rhomboidal. This salt is known by the name of Vitriol of Zinc, White Vitriol, Sulphate of Zinc: its taste is considerably styptic. It is not much altered by exposure to air when pure; but suffers its acid to escape, at a degree of heat less than is required by the sulphate of iron.

The nitric acid attacks zinc with vehemence, even when diluted with water. In this operation a great part of the acid is decomposed; but if the residue be concentrated by

slow evaporation, crystals are obtained in compressed and striated tetrahedral prisms, terminated by pyramids with four sides. Mr. De Fourcroy, to whom we are indebted for this observation, adds, that the salt melts upon heated coals, and spreads abroad with decrepitation, and a small reddish flame. If it be exposed to heat in a crucible, it emits red vapours, assumes the consistence of a jelly, and preserves this softness for a certain time. The nitrate of zinc is very deliquescent.

The muriatic acid attacks zinc with effervescence. Hydrogenous gas is produced, and black flocks are precipitated, which some chemists have taken for sulphur, others for iron, and which Mr. De Laffone considers as an irreducible oxide of zinc. This evaporated solution becomes thick, and refuses to crystallize. It suffers a very concentrated acid to escape when heated, and the muriate itself sublims by distillation.

The pure alkalis boiled on zinc obtain a yellow colour, and dissolve a part of the metal, as Mr. De Laffone has proved. Ammoniac digested in the cold upon this semi-metal, disengages hydrogenous gas: this evidently arises from the decomposition of the water, which alone, and without any mixture, is decomposed upon ignited zinc, as we have already observed.

Zinc mixed with the nitrate of pot-ash, and thrown into an ignited crucible, causes this salt to detonate strongly.

Zinc decomposes the muriate of ammoniac by simple trituration, according to Mr. Monnet.

Pott has observed that a solution of alum, boiled upon the filings of zinc, is decomposed, and affords the sulphate of zinc.

Zinc fused with antimony, forms a hard and brittle alloy.

It unites with tin and copper, and forms bronze; when combined with copper alone, it forms brass.

It is mixed with gunpowder, to produce the white and brilliant stars of artificial fire-works.

It has been proposed to substitute this metal in the room of tin, for the internal lining of copper vessels; and it is ascertained from the labours of Mr. Malouin, that this covering would be more uniformly extended upon the copper, and would be harder than tin. It has been remarked that

vegetable acids might dissolve it, and that these salts are dangerous; but Mr. de la Planche has made all the experiments on this subject which his extensive knowledge, and zeal for the public good could inspire; and he is convinced that the salts of zinc, taken in a more considerable dose than the aliments prepared in vessels tinned with this semi-metal might contain, are not dangerous.

The sublimed oxide of zinc is much employed by the German physicians, under the name of Flowers of Zinc. This remedy is given as an antispasmodic. It may be administered in pills, in the dose of one grain. Tutty, or pompholix, is mixed with fresh butter, as an excellent remedy in disorders of the eyes.

Mr. De Morveau has substituted the precipitate of zinc to white lead, with the greatest advantage. It perfectly answers the intention of the artist, and is not attended with any dangerous consequences in its use.

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## CHAPTER VII.

### *Concerning Manganese.*

A MINERAL of a grey or blackish colour, soiling the fingers, and used in glass-houses under the name of Soap of the Glass-makers, has been long known in commerce. Most naturalists, such as Henckel, Cramer, Gellert, Cartheuser, and Wallerius, have placed it among the iron ores. Pott and Cronstedt did not consider it as a ferruginous substance. The latter found it to contain tin; and Mr. Sage was long of opinion that it was an intimate alloy of zinc and cobalt.

The celebrated Bergmann, in the year 1764, declared in print, that black manganese ought to contain a peculiar metal; but he attempted in vain to extract it. However, Mr. Gahn, a physician at Stockholm, succeeded in obtaining a metal by the assistance of an exceedingly strong fire. We shall explain his process after having spoken of the different forms under which manganese is found in the earth.

Manganese appears to be always found in the state of oxide; but this oxide exhibits several varieties.



1. It is sometimes grey, brilliant, and crystallized, formed of very slender prisms confusedly intertwined, and resembling the ore of antimony; from which however it may be easily distinguished by exposing it upon charcoal. For antimony fuses, and affords vapours; but the manganese remains unchanged.

The crystals of manganese are striated, tetrahedral, rhomboidal prisms, terminating in four-sided pyramids. They frequently diverge from a centre.

2. Manganese is very often black and friable. This species is found in the cavities of the brown hæmatites of the Pyrenean Mountains.

I have discovered an ore at St. Jean de Gardonenque, in the Cevennes. It is prodigiously light, is found in strata, and in pieces which almost always have the figure of an hexahedral prism, eighteen lines in length, and thirteen or fourteen in thickness.

This ore, upon which I have made experiments that I shall presently recite, is the purest and finest I am acquainted with.

3. Manganese is sometimes of a reddish white colour, and composed of groups of protuberances. Its fracture is lamellated. That of Piedmont frequently has a grey, reddish tinge, and appears to be composed of small plates. It gives fire with the steel.

The manganese of Macon in Burgundy is of a deeper grey than that of Piedmont.

That of Perigueux is intermixed with yellow martial ochre. It is found in separate bodies, and not in veins like that of Piedmont.

4. Most of the white spathose iron ores contain manganese, and may be considered as ores of this semi-metal. Manganese is likewise mixed with calcareous spar, gypsum, jasper, hæmatites, &c. Mr. De la Peyrouse has described thirteen varieties of crystallized manganese found in the Pyrenean Mountains.—See the *Journal de Physique*, Jan. 1780, p. 67.

5. Scheele has proved that the ashes of vegetables contain manganese; and it is to this mineral that the colour of calcined pot-ash is owing. To extract it, three parts of fixed alkali, one of sifted ashes, and one-eighth of nitrate, must



be fused together. The fluid mixture must then be poured into an iron mortar, where it congeals into a greenish mass. This being pounded, and boiled in pure water, must be filtrated, and saturated with sulphuric acid. At the end of a certain time, a brown powder is deposited, which possesses the properties of manganese.

To reduce manganese to the metallic state, a crucible is lined with charcoal; and into a hole made in this charcoal, a ball of manganese, previously kneaded with oil and gum ammoniac, is to be put; after which the hole is to be covered with powder of charcoal. Another crucible must then be fitted on, and the vessels exposed to a violent fire for an hour and a half. By following this process, I have several times obtained the metal from the oxide of manganese of Cevennes. I have even succeeded in reducing it, by simply putting the powder of manganese into a lined crucible.

The button which is obtained almost always has asperities on its surface. Globules appear which scarcely adhere to the mass; and these portions are usually of a considerably deep green, while the internal part has a blueish cast.

This metal is more infusible than iron. I have several times observed, when the fire has not been sufficiently strong to fuse the manganese, that several globules of iron have appeared dispersed through the agglutinated oxide.

Saline fluxes ought to be rejected, as insufficient for this reduction. The great disposition which this semi-metal has to become vitrified, causes it to be dispersed in the flux, where it remains suspended. I have several times, by using the vitreous flux of Mr. De Morveau, obtained metallic grains forming a button, or else dispersed in the flux; which, when more narrowly examined, proved to be nothing but iron, cobalt, or other metals, according to the nature of the ore of manganese. I have sometimes obtained even globules of lead; because the coarsest glass in which the presence of that metal is the least suspected, and which enters into the composition of the flux of Mr. De Morveau, contains it very often.

The specific gravity of manganese has been estimated by Bergmann, in proportion to that of water, nearly as 6350 to 1000.

The oxide of manganese, when strongly heated in close vessels, affords a prodigious quantity of oxygenous gas, and begins to afford it at a degree of heat less than is necessary to disengage it from the oxides of mercury: a strong fire is required to disengage the last portions. Four ounces of the manganese of Cevennes afforded me nine pints of oxygenous gas. The residue in the retort was a grey oxide; one part of which was incrustated in the fused glass, and had communicated to it a very rich violet colour.

The oxide of manganese, distilled with charcoal, affords the carbonic acid: but, if it be calcined in an open vessel, it is reduced into a grey powder, which loses considerably of its weight when the fire is very strong; and at length agglutinates, and forms a green mass.

If it be mixed with charcoal, it does not suffer any perceptible change in its colour.

Manganese, exposed to a very violent heat, vitrifies, and affords a glass of an obscure yellow colour. The iron which is mixed with it preserves its metallic form.

Manganese is easily changed in the air, and is resolved into a brown powder of a greater weight than the semi-metal itself; a certain proof of oxidation.

Manganese unites easily by fusion with all the metals except pure mercury. Copper alloyed with a certain quantity of manganese is still very malleable.

If a mixture of the phosphate of urine with a small quantity of oxide of manganese be placed upon charcoal, and be kept in fusion for a few instants by means of the blue interior flame of the blow-pipe, a transparent glass will be produced, of a blue colour inclining to red; which, when charged with a certain quantity of the salt, assumes the colour of a ruby. If it be kept in fusion for a longer time, a slight effervescence is perceived, and all the colour disappears. If the transparent globule be then softened by the exterior flame, the colour soon returns, and may be again effaced by keeping up the fusion for a time. The smallest portion of nitrate, added to the glass, immediately restores the red colour; and, on the contrary, it is destroyed by the addition of sulphuric salts. This globule of glass, taken from the charcoal, and fused in the spoon of perfect metal, becomes red, and changes no more. These experiments were made by the celebrated Bergmann.

The sulphuric acid attacks manganese, and produces hydrogenous gas. This metal is dissolved more slowly than iron; a smell is disengaged similar to that which is afforded by the solution of iron by the muriatic acid. The solution is as colourless as water, and affords by evaporation transparent colourless crystals in the form of parallelepipeds, and of a bitter taste. Mr. Sage obtained them in tetrahedral prisms, terminated by four-sided pyramids. This salt effloresces in the air.

If the sulphuric acid be poured on the oxide of manganese, and its action assisted by a gentle heat, an astonishing quantity of oxygenous gas is disengaged. The oxide of manganese of Cevennes afforded me five pints and a half per ounce. When this oxide is deprived of its oxygen, the residue is a white powder, soluble in water, which by evaporation affords the sulphate of manganese, already described.

The celebrated Bergmann has observed that coaly matter, such as sugar, honey, and gum, assisted the action of the acid. This depends on the combination of the oxygen with these agents, to form the carbonic acid; and the sulphuric acid acts more easily upon the metal itself.

Manganese is precipitated from its solutions by the alkalis, in the form of a whitish gelatinous matter; but this precipitate soon loses its colour, and becomes black by the contact of the air. This phenomenon, which I have myself been a witness to, can be attributed, in my opinion, only to the absorption of oxygenous gas: and I was convinced of this truth by agitating the precipitate in bottles filled with this gas; for in this situation the black colour is produced in one or two minutes, and a considerable part of the gas is absorbed. I have constructed an eudiometer as certain and as invariable as that which the liquid sulphure of potash, or solution of liver of sulphur, affords; but a large quantity of precipitate is required, which must be agitated against the sides of the vessels, in order that it may present a greater surface to the air, and that the absorption may be more speedy. I judge of the absorption by causing the vessel to communicate, by a graduated tube, with standing water. The ascension of this water in the tube is proportionate to the volume of oxygenous gas absorbed.



The nitric acid dissolves manganese with effervescence. There always remains a black, spongy, and friable body, which exhibited to Bergmann all the characters of molybdena. Other solvents presented a similar residue. The solution of the nitrate of manganese has frequently a dull colour, and assumes the red colour with difficulty. This solution does not afford solid crystals, even by slow evaporation.

The oxides of manganese are soluble in the nitric acid. It is observable that this acid is not decomposed upon them, because it finds the metal in the state of oxide. Carbonic acid is afforded when coaly substances are added to assist the solution. When the nitrous or fuming nitric acid is used, the solution is made without the assistance of these coaly substances, because the excess of nitrous gas seizes the oxygen of the oxide. These solutions do not crystallize.

The muriatic acid dissolves manganese; but when it is digested upon the oxide it seizes the oxygen, and passes in vapour through the water. This vapour is known by the name of Oxygenated Muriatic Acid, whose properties we have already explained.

The residue in the retort consists of a portion of acid combined with the manganese. This by evaporation affords a saline mass, which attracts the humidity of the air.

The fluoric acid with manganese affords a salt of sparing solubility, and this acid dissolves but little of it: but by decomposing the sulphate, the nitrate, or the muriate of manganese by the fluates of ammoniac, a fluuate of manganese is precipitated. The same phenomenon takes place with the phosphoric acid. The acetic acid has but a weak action upon this substance. If it be digested upon the oxide of manganese, it acquires the property of dissolving copper, and forms the beautiful acetate of copper, or crystals of Venus; whereas the same acid, digested on copper, forms verdigris, or simply corrodes it. This circumstance proves that the acetic acid becomes charged with oxygenous gas, by the assistance of which it dissolves the copper.

The oxalic acid not only dissolves manganese, but likewise the black oxide of manganese. The saturated solution deposits a white powder, if there be not an excess of acid. This salt is blackened by the fire, but easily resumes the



milky colour in the same acid. The oxalic acid precipitates it in the form of small crystalline grains, when poured into solutions made by the sulphuric, nitric, or muriatic acids.

The acidulous tartrate of pot-ash dissolves the black oxide, even in the cold. The tartrate of pot-ash added to any solution whatever of manganese, occasions a precipitate which is a true tartrate of manganese.

The carbonic acid attacks manganese and the black oxide. The solution becomes covered in the open air with a pellicle, which consists of manganese that is separated and oxidized. It is white when it does not contain iron.

If the muriate of ammoniac be distilled with this oxide of manganese, an elastic fluid is disengaged, according to the observation of Scheele, which he considers as one of the principles of ammoniac, without determining its nature. Mr. Berthollet has proved that, when ammoniac is disengaged by a metallic oxide, there is a portion decomposed. The oxygen of the oxides unites to the hydrogenous gas of the alkali to form water, and the nitrogenous gas escapes.

Eight parts of oxidized manganese take up, by a gentle heat, in a glass retort, three parts of sulphur; and produce a mass of a greenish yellow colour, which acids attack with an effervescence and hepatic smell.

Manganese itself does not appear to combine with sulphur.

In order to separate iron from manganese, the alloy must be dissolved in the nitric acid, and evaporated to dryness. The residue must be strongly calcined, and digested with weak nitric acid, and a small quantity of sugar. The acid takes up the manganese, which may be precipitated by the carbonate of pot-ash.

The alloy may likewise be put into a solution of the sulphate of iron. The acid abandons the iron to unite with the manganese.

The iron having less affinity with the acid than the manganese, may likewise be precipitated by a few drops of alkali.

The oxide of manganese is chiefly used in glass-houses, to deprive glass of its green or yellow colour, which soda and sand, when fused together, usually assume. It has on this account been called the Soap of the Glass-makers. It is also used to colour glass and porcelain of a violet colour.

The consumption of this mineral is become more considerable since the discovery of the oxygenated muriatic acid, which has pointed out its uses in bleaching of linen, cotton, &c.

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## CHAPTER VIII.

### *Concerning Lead,*

**LEAD** is the softest, the least tenacious, the least sonorous, the least elastic, and one of the most ponderous, of metals. A cubic foot of lead weighs seven hundred and ninety four pounds, ten ounces, four gros, forty-four grains. Its specific gravity is to that of water as 115523 to 10000. according to Brisson. Its fracture is of a blueish white colour, darker than that of tin, and tarnishing in the air. It possesses a peculiar smell, which is rendered perceptible by friction.

A gentle heat is sufficient to fuse lead; and the abbé Mongez obtained it in crystals of the form of quadrangular pyramids, recumbent on one side. Some authors affirm that lead is occasionally met with in the native state. Wallerius mentions three pieces of this kind. The German mineralogists likewise affirm that it has been found native in Villach in Carinthia. Mr. Genissane found in Vivarais, in four places, at Serremejanes, at Fayet near Argentiére, at St. Etienne de Boulogne, and near Villeneuve de Berg, “grains of native lead, from the size of a chestnut to an “almost imperceptible degree of smallness; they are all “included in a very ponderous metallic earth, which is “precisely of the colour of the ashes of beech, or of “litharge reduced to an impalpable powder. This earth “may be cut with a knife, but requires the hammer to “break it.” He found pieces which contained a substance similar to litharge in their internal part.

Linnæus speaks likewise of a native lead in crystals.—Most naturalists agree to consider native lead as of a very problematical existence. The various samples found in cabinets are probably owing to ancient mine works. Time has changed their appearance, and incrustated them with various

matters, which seem to prove that they do not owe their formation to the action of fire; and this is the circumstance which may have imposed on certain naturalists.

1. Lead is usually mineralized by sulphur; and this ore is known by the name of Galena.

It usually crystallizes in cubes, and in all the varieties of that figure.

Galena is distinguished into several species. 1. Large diced galena. 2. Small diced galena. 3. Scaly or plated galena. 4. Compact galena, in small brilliant grains resembling steel. It does not appear to be lamellated.

These distinctions are more especially necessary to be attended to, because the species are very different in richness, and the alloy of silver, which is inseparable from galena. In general, the large diced galena is poor in silver, and is used to give a glaze to pottery, by the name of Alquist, or potters lead ore. That which is in small grains is richer, and is wrought as a lead ore containing silver.

Galena is the only species of lead ore which is worked; and we shall relate all we have to say concerning the working and assay of lead ores after having spoken of the other ores.

2. Lead has been found mineralized by the sulphuric acid. Mr. Monnet has called this ore the pyritous lead ore. It is friable, dull, black, and almost always crystallized in very long needles, or in stalactites. It effloresces in the air, and affords a true sulphate of lead. This appears to be of the nature of galena: for as the sulphate is not developed but by the efflorescence of the ore, it may be concluded that the sulphuric acid does not exist in the virgin ore itself.

Lead mixed with iron is sometimes combined with the sulphuric acid. A large quantity is found in the island of Anglesea. It cannot be reduced upon charcoal with the blow-pipe, but it fuses into a black glass.—Dr. Withering has indicated this ore.

3. The carbonic acid very often mineralizes lead, and exhibits some varieties which we shall proceed to describe.

A. The white lead ore.—This is almost always found in the cavities of decomposed galena, or in the veins of powdery stone containing galena. It is heavy, and frequently

of a greasy colour; decrepitates in the fire; and is easily reduced by distillation, affording only water and the carbonic acid. Its form is almost always crystalline, but varies prodigiously. The primitive form appears to be a dodecahedron, with isosceles triangular planes.

I have seen crystals accurately of the form of an hexahedral prism sometimes terminated by a six-sided pyramid. The ores of St. Sauveur in the Cevennes have afforded us this variety; Mr. Sage possesses white lead ore of Geroldseck crystallized in cubes.

White lead as transparent as flint glass has been found in England and in Siberia.

The analysis of the white lead of Siberia afforded Mr. Macquart, per quintal, sixty-seven parts lead, twenty-four carbonic acid, six oxigene, and three water.

**B. Green lead ore.**—This differs from the foregoing only in the modifications produced by the colouring principle, which is copper, according to Spielman; and iron, according to the greatest number of chemists. Its form is usually that of a truncated hexahedron; and this ore is not so easily reduced as the white ore.

**C. The black ore of lead.**—Lead may return to the state of galena by resuming the sulphur it had lost; and this regeneration is not rare. It is enough that any hepatic vapour should strike the ore to effect this conversion. The ores of Tschopau in Saxony, and those of Huelgoet in Lower Brittany, exhibit fine instances of this phenomenon.

The gradations or intermediate specimens of these different ores, establish an infinite number of species, which the naturalist can never admit but as varieties. The transition of the white lead ore to the black ore exhibits gradations of colour which it would be very superfluous to describe.

In the year 1766, Mr. Lehmann described a new species of lead ore, called Red Lead. It was found in Siberia, in the environs of Catherineburg. Its crystals are grouped, and adherent to quartz, to copper ores, or iron; and sometimes to galena, with crystals of white and green lead. It is frequently crystallized in rhomboidal tetrahedral prisms, short, and truncated obliquely.

Mr. Sage has considered this lead ore as a variety of the preceding species, coloured by iron, of which Mr.



Lehmann has proved the existence. The abbé Mongez thinks it is mineralized by the arsenical acid.

Mr. Macquart has given us the most valuable information respecting the red lead ore; and has proved by an accurate analysis that it contains, in the quintal, lead thirty-six, oxigene thirty-seven, iron twenty five, and alumine two.

4. The phosphoric acid has likewise been found naturally combined with lead. This ore, discovered by Gahn, owes its green colour to iron. It does not effervesce with acids. In order to assay it, it must be dissolved in the nitric acid by the assistance of heat, and the lead may then be precipitated by the sulphuric acid. The supernatant liquor being decanted off, and evaporated to dryness, affords the phosphoric acid.

This ore melts by the blow-pipe, and affords an opaque globular mass without reduction. Its habitudes with fluxes resemble those of lead and its oxides.

Mr. De la Metherie has informed us that Mr. \* \* \*, an English gentleman, by treating lead ores with the blow-pipe, had observed that there was one whose globule crystallized by cooling, after having been in perfect fusion; and that these ores were not reducible by the blow-pipe. He suspected they were mineralized by the phosphoric acid. Mr. De la Metherie and this gentleman took seven ounces of the green lead ore of Hoffsguard, near Fribourg in Brisgaw; which, when treated by the foregoing process, afforded them phosphoric acid. The phosphoric acid combined with minium afforded them a green compound.

The decomposition of the ores which we have described frequently affords the oxides of lead, or calciform ores.

These oxides at first afford a powder which, being carried along by waters, often mixes with argillaceous, calcareous, or quartzose earths.

These oxides vary more particularly in their colour, which assimilates them more or less perfectly to ceruse, massicot, or minium.

In order to make the assay of a galena, it must be pulverized and torrefied. The torrefied mineral, mixed with three parts of black flux, affords by fusion a metallic button, which indicates the proportions of the lead in the quintal of the ore.

Bergmann proposes to make the assay of sulphureous lead ores by the nitric acid, which dissolves the lead and not the sulphur. The solution is then to be precipitated by the carbonate of soda; and one hundred and thirty-two grains of the precipitate are equivalent to one hundred of the metal. If the ore contains silver, ammoniac is to be digested on the precipitate, from which it dissolves the oxide of silver.

The various operations to which lead ore is subjected to obtain the lead, are—1. It is sorted, to separate the rich or pure ore from the pulverized matter, and the gangue which contains no metal. 2. The ore is pulverized, and its gangue separated by washing. 3. The ore is roasted in a reverberatory furnace, with occasional agitation, that it may present all its surfaces to the air; and when the external part begins to assume the form of a paste, it is covered with charcoal, the mixture is stirred, and the heat increased. The lead then runs on all sides, and is collected at the bottom of the furnace, which is pierced, and permits the metal to flow into a receptacle properly defended by a lining of charcoal.

The scoriæ, which still retain much lead are fused by a blast furnace: the lead is cast into pigs for sale.

To disengage the silver which the lead may contain, it is carried to the refining furnace; where, by the united energy of fire, and the wind of bellows directed upon the melted lead, the metal is converted into a yellow scaly oxide, called Litharge. This litharge is driven off in proportion as it forms; and the silver remains alone in the middle of the cupel. The colour causes a distinction of the litharge into litharge of gold, or litharge of silver. When the litharge is fused in contact with charcoal, it resumes its state of metal; and the lead is so much the better, in proportion as it has been deprived of the silver it contained. The smallest alloy of fine metal renders it brittle.

Lead is fusible by a gentle heat. If it be kept for some time in fusion, it becomes covered with a grey oxide; which, when exposed to a more violent heat capable of keeping it ignited, assumes a deep yellow colour, in which state it is called Massicot. Massicot may be converted into the red oxide, or minium, by the following process.

When the lead is converted into massicot, it is thrown out and cooled by pouring water upon it; after which it is carried to the mill, and ground into very fine powder, which is washed in water. The particles of lead which could not be pulverized in the mill, remain in the vessel where the washing is performed.

This oxide of lead is spread out upon the hearth of the furnace in which it is calcined. Lines are drawn on its surface; and it is stirred from time to time, that it may not clot together; and the fire is kept up for forty-eight hours. When the minium is taken out of the furnace, it is put into large sieves of wood, and passed through very fine net work, or cloth of iron wire, placed over the casks which receive the minium. We are indebted to Messrs. Jars for this information, who have given very curious details respecting the manufactories of minium in the county of Derby.

Mr. Geoffroy was of opinion, that, in order to form minium, no greater heat was required than one hundred and twenty degrees of Reaumur's thermometer. but this heat is not adapted to works on a large scale; for in these the roof of the furnace is kept at a red heat. The lead increases in weight ten per cent. by the calcination.

All these oxides, urged by a stronger heat, are converted into a yellow glass, so very fusible, that it penetrates and destroys the best crucibles. It is used in glass-houses, on account of its fusibility, not only to assist the fusion, but likewise to render the glass softer, more ponderous, of a more unctuous feel, and more susceptible of being cut and polished. These are the reasons for which it is made a part of the composition of flint glass, and crystal glass.

The oxides of lead, distilled without addition, afford oxygenous gas by a violent heat.—Priestley obtained it from minium, part of which was converted into globules of metal.

When these oxides are fused with coaly matter, the metal becomes revived.

The sulphuric acid boiled upon lead affords much sulphureous acid; and an oxide is formed, which arises from a combination of the oxygen of the acid with the lead. A portion of the lead is nevertheless dissolved; for if a suffi-

cient quantity of water be poured on the residue, a very caustic salt is obtained by evaporation, in tetrahedral prisms, soluble in eighteen times their weight of water. This sulphate is decomposed by fire, lime, the alkalis, &c.

Very hot sulphureous acid, poured into a leaden vessel, corrodes and destroys it instantly.

The concentrated nitric acid is readily decomposed upon lead, and converts it into a white oxide; but when the acid is weak it dissolves the metal, and forms crystals of an opake white, in the form of segments of a three-sided prism. I have specimens of the nitrate of lead in my laboratory, which possess the form of truncated hexahedral prisms; three of the sides being broader than the others, and exactly similar to those which Mr. De Fourcroy obtained by insensible evaporation.

This salt decrepitates in the fire, and is fused with a yellowish flame upon ignited coals. The oxide of lead becomes yellow, and is reduced into globules or metal. Sulphuric acid takes lead from the nitric acid.

The muriatic acid, assisted by heat, oxides lead, and dissolves a portion. This salt crystallizes in striated hexahedral prisms.

This muriate is slightly deliquescent. Lime and alkalis decompose it.

The same acid poured on litharge decomposes it instantly. Fifty or sixty degrees of heat are produced. The solution affords fine octahedral crystals, of an opake white colour, a styptic taste, and of very considerable weight.

This salt decrepitates on the coals; and when the fire is increased, its water of crystallization escapes, and it becomes converted into a mass of a beautiful yellow colour.

Three parts of water, at fifteen degrees of temperature, dissolve one part; and boiling water more than its weight.

The pure alkalis precipitate it in the form of a magma, which occasions a kind of *miraculus mundi*.

The affinity of the muriatic acid with the oxide of lead is so strong, that it is capable of decomposing all its combinations. Minium or litharge decomposes the muriate of ammoniac. The same oxides, triturated with marine salt, separate the soda; and it is upon these facts that Mr. Turner



and others have established manufactories for procuring soda by the decomposition of marine salt\*.

The muriates of lead, calcined or fused, afford a pigment of a beautiful yellow colour. The manufactories of soda have afforded a very considerable quantity, which is substituted instead of the fine Naples yellow.

4. The acetous acid corrodes lead; and affords a white oxide known by the name of white lead.

To prepare this colour, the lead is melted, and cast into plates about half a line in thickness, four or five inches wide, and two feet long. These are rolled up in a spiral form, in such a manner that the revolutions remain at the distance of half an inch from each other. They are then placed in pots, upon three points, which project from the inside at about one third of the height. Malt vinegar is poured into these pots to the height of the bottom of the lead, and they are buried in dung beneath sheds. A great number of these are disposed beside each other, and several strata are formed. Care is taken to cover each pot with a plate of lead and boards. At the expiration of a month or six weeks they are taken out, and the white lead is separated. This white calx is then ground in mills, and afterwards put into a vat, from which it is taken out to dry. The drying is performed in the shade, because the sun impairs the colour. For this purpose it is put into small conical earthen pots; and when sufficiently dry it is wrapped in paper, and distributed for sale.

Ceruse does not differ from white lead, excepting that a more or less considerable quantity of chalk is mixed with it.

All the oxides of lead are soluble in vinegar. The solution of the acetate of lead, duly concentrated, crystallizes in efflorescent tetrahedral prisms; and forms the salt of saturn, or sugar of lead.

Caustic alkalis dissolve the oxides of lead, and the metal may be precipitated by the addition of acids. When the

\* I do not hear that soda has been separated from common salt by a method sufficiently cheap for the purposes of commerce. It is universally understood that Mr. Turner's profits arise from the sale of the combination of muriatic acid with the lead, which forms the yellow pigment known in London by the name of Patent Yellow. It may be produced simply by the fusion of litharge and common salt; the alkali being volatilized, and driven off, if the fire be sufficiently intense. T.

alkaline solution is concentrated, the lead re-appears nearly in the metallic form, and the alkali is found to have acquired a faint and very peculiar taste.

The uses of lead in the arts are multifarious. It is used to make water pipes, boilers, coverings for the roofs of buildings, tea-chests, and other articles of package. It is rendered proper for these uses, either by laminating it, or by causing it to flow out upon a bed of sand well rammed and levelled, or upon the cloth called ticking.

It is likewise used to make bullets and small shot. The bullets are cast in moulds; but the small shot is made in the following manner:—Lead is fused with a small quantity of arsenic, to render it more brittle; and when its temperature is such as to admit of a card being plunged in it without burning, it is poured into a kind of cullender, pierced at the bottom with many holes, and containing lighted charcoal: this cullender is held over water; and the lead assumes a round form as it enters this liquid.

Lead is used in the tinning of copper vessels. This is a pernicious fraud supported by custom, and tolerated by the want of vigilance in the police. It is the more dangerous from the circumstance that fats, oils, and vinegar corrode or dissolve lead, which by that means becomes mixed with the aliments.

Lead ore is likewise used to glaze pottery. For this purpose galena is pulverised, and mixed with water. The vessel intended to be glazed is dipped into this fluid, after having been exposed to a first baking. It accordingly becomes covered with the galena; which, when exposed to a violent heat, passes to the state of glass, and forms a covering of the glass of lead over the whole surface. This process is attended with the inconvenience of introducing a dangerous poison into our culinary vessels whose effects on the health of individuals cannot but be sensibly felt.

Oxided lead enters into the composition of glasses, crystals, and enamels. It possesses the advantage of facilitating the fusion, and giving the glass an unctuous feel, and a degree of softness, which renders it capable of being cut and polished.

White lead and ceruse are used by painters. These oxides possess the singular advantage of not being percep-

tibly altered by their mixture with oil; and form, by their whiteness and body, a basis or receiver, which is very suitable for a variety of colours. The workmen who grind these colours are affected by them; and sooner or later become subject to the painters colic, *colica pictorum*.

Litharge is at present used to decompose sea salt; and the muriate of lead by fusion forms a superb yellow, very much employed in varnish colours.

8. Ceruse is likewise much used for drying up habitual moisture of the skin, and for slight burns. It is applied to the skin in the form of powder, and there is no remedy more speedy.

The salt of saturn, or sugar of lead, is almost entirely used by the callico printers.

The vinegar of saturn, or the vegeto-mineral water of Mr. Goulard, is a very proper astringent in the consequences or remains of venereal disorders: it is likewise used to wash burns and ulcers, and to facilitate their cure.

This extract is likewise used to clarify liquors, and to deprive brandies of their colour; an evil practice which has been common for some years at Sette, though prohibited under heavy penalties.—The wine merchants avail themselves of this composition but too often, or of litharge, to render their four wines sweet. This fraud was prodigiously common at Paris in the year 1750; and it was proved that, in the interval of three years, thirty thousand muids of vinegar had been thus sweetened; and sold for wine.

The oxides of lead are likewise used to harden oils, or to render them more drying. In this operation the oxigene of the oxide combines with the oil, and causes it to approach nearer to the nature of resins. There is likewise a solution of lead in oils, which serves as the basis of plasters.

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## CHAPTER IX.

### *Concerning Tin.*

**T**IN is a metal of a white colour, intermediate between that of lead and silver. It is very flexible; and produces a crackling noise when bended. No other metal



possesses this property except zinc, in which it is infinitely less marked.

This metal is very soft, and the lightest of any of the entire metals. The specific gravity of fused tin is 7,2914, according to Brissou.

A cubic foot of this metal weighs about five hundred and ten pounds. It is very ductile under the hammer; and its tenacity is such, that a wire one tenth of an inch in diameter is capable of supporting forty-nine pounds eight ounces without breaking. Mr. De la Chenaye has crystallized tin after several repeated fusions; he obtained by this means an assemblage of prisms united together sideways.

Tin has been found in the metallic state in the bowels of the earth. Mr. Sage possesses a specimen from the mines in Cornwall, and Mr. De Lisle likewise has one in his collection. This tin, so far from exhibiting any trace of fusion, has the external appearance of molybdena: it is easily broken; but the detached pieces may be flattened by the hammer.

Tin ore is either white or coloured.

1. The white tin ore, which has been often confounded with tungsten, crystallizes in octahedrons. Its texture is lamellated, and it frequently includes portions of reddish tin ore. That of Cornwall afforded Mr. Sage sixty-four pounds of tin in the quintal.

2. The coloured tin ore does not differ from the preceding, excepting that it contains iron, and sometimes cobalt. This ore usually has the form of irregular polyhedrons.

These ores afford carbonic acid by distillation when exposed to fire in a crucible. They decrepitate, lose somewhat of their colour, and become one-tenth less heavy.

Bergmann found sulphureous tin among the minerals he received from Siberia. He affirms that this was of a golden colour externally, resembling aurum musivum; and internally it presented a mass of radiated, white, brilliant, brittle crystals, which assumed changeable colours on exposure to the air.

To assay a tin ore, nothing more is necessary than to fuse it in the midst of the coals. Calcination in the open fire dissipates much of the metal, according to the observation of Cramer.



In the working of tin ores, the mineral must be sorted very exactly; after which it is to be pulverized, and washed upon tables covered with cloth. By agitation with a wisp or broom, the gangue is suspended or carried away by the water, and the tin ore remains alone.

The furnace made use of in Saxony for the fusion of tin ore, is a variety of the blast furnace, on the hearth of which is a groove to receive the melted metal, and convey it into a basin; whence it is taken to be cast in moulds of copper or of iron.

The tin ores of Cornwall are frequently mixed with copper, and arsenical pyrites. The quartz, which is its gangue is very hard; and on this account the operation is begun by torrefaction of the ore before it is pulverized. After the ore is washed, a separation of the magnetical iron is effected by means of loadstones. The ore is usually fused in the reverberatory furnace.

In Saxony, and in England, the scoriæ are three times fused to separate the tin, after which they are pounded to separate the last portions of metal. As the vein of tin in the mines of Cornwall is always mixed or accompanied with a vein of copper, the tin must contain this latter metal, however great the precautions which may be attended to in the working.

We are acquainted with three kinds of tin in commerce.

1. Pure tin, such as that of Malacca, of Banca, and the soft tin of England. The tin of Malacca is cast into moulds which give it the form of a quadrangular truncated pyramid, with a small rim at its base. It is called, in France, *Etain en Chapeau*, or *en Ecritoire*. Each ingot weighs one pound.—The tin of Banca is in the form of oblong ingots, weighing from forty to forty-five pounds each.

2. The English tin, in large pigs, is cast into sticks of ten or twelve lines in diameter, and a foot and a half long.

3. The tin of the pewterers is alloyed with various metals. The law in France permits them to add copper and bismuth; and they of their own authority add zinc, lead, and antimony.

Every kind of tin enters into fusion with considerable facility, for it is the most fusible of the metals. If it be kept in fusion for a short time, exposed to the action of the

air, the surface becomes wrinkled, and covered with a grey pellicle. If this first covering be taken off, the tin appears with all its brilliancy; but soon becomes dull, and is oxidized again. Tin gains one-tenth of its weight by this calcination. When the oxide is white, it is then called Putty. It is this oxide of tin which the makers of pewter spoons, who usually travel over the country, call the Dross of Tin. They are very careful to scum the metal as often as possible, to clear it of the dross; and by this means they avoid giving the peasant any more of his old pewter than that which they cannot contrive to take away from him. They are very well acquainted with the art of fusing this pretended dross into good tin, by heating it in contact with charcoal.

The putty of tin is used to polish hard bodies: and to render glass opaque, which converts it into enamel. Tin takes fire by a violent heat, according to Geoffroy; and a white oxide sublimes; while part of the tin is converted into a glass of an hyacinthine colour.

If tin be kept in fusion in a lined crucible, and the surface be covered with a quantity of charcoal to prevent its calcination, the metal becomes whiter, more sonorous, and harder, provided the fire be kept up for eight or ten hours.

Tin, and several other metals, may acquire a brilliancy they do not usually possess, by pouring them out at the moment before they would congeal in the crucible. This treatment secures them from the oxidation they suffer in cooling, when they are poured out too hot; and by this method, which is very simple, I have procured to tin and lead a degree of brilliancy which they would hardly be thought capable of exhibiting.

Tin, distilled in close vessels, affords a white sublimate in the neck of the retort, which Margraff took for arsenic; but Messrs. Bayen and Charlard have proved that it was not that substance.

The action of acids upon tin varies according to the degree of purity of the metal.

The sulphuric acid of commerce dissolves tin, by the assistance of heat; but part of the acid is decomposed, and flies off in the form of very penetrating sulphureous acid. Water alone precipitates this oxidized metal. Mr. Monnet

has obtained crystals by calcination, which resemble fine needles, interlaced among each other. The sulphuric acid dissolves the oxide of tin much better.

The nitric acid devours tin. The decomposition of this solvent is so speedy, that the metal is seen to be precipitated, almost instantly, in a white oxide. If this acid be loaded with all the tin it is capable of calcining, and the oxide be washed with a considerable quantity of distilled water, a salt may be obtained by evaporation, which detonates alone in a crucible well heated, and which burns with a white and thick flame, like that of a phosphorus. The nitrate of tin, distilled in a retort, swells up, boils, and fills the receiver with a white and thick vapour, which has the smell of nitric acid.

Mr. Baumé even pretends that the nitric acid does not dissolve tin; but Kunckel, and the famous Rouelle, have maintained the contrary. Messrs. Bayen and Charlard dissolved five grains in two gros of pure nitric acid, diluted with four gros of distilled water.

The muriatic acid dissolves tin, whether cold or heated. During the effervescence, a very fetid gas is disengaged. The solution is yellowish, and affords needle-form crystals by evaporation, which attracts the humidity of the air. Mr. Baumé prepared this salt in the large way for the callico printers. Out of twelve pounds of tin, dissolved in forty-eight pounds of acid, he had a residue of two ounces six gros of a grey and soluble powder, which Margraff had taken for arsenic. Mr. Baumé has observed that the crystals of the muriate of tin differ according to the state of the acid. He obtained crystals, similar to those of the sulphate of soda, in needles, or in scales like those of the acid of borax. Mr. Monnet asserts that he obtained, by the distillation of a muriate of tin, a fat matter, a true butter of tin, and a liquor resembling that of Libavius.

The oxygenated muriatic acid dissolves tin speedily; and the salt which it produces, possesses all the characters of the ordinary muriate, according to Mr. De Fourcroy.

That which is known by the name of the Fuming Liquor of Libavius, appears to me to be a muriate of tin, in which the acid is in the state of the oxygenated muriatic acid. To make this preparation, tin is amalgamated with one-fifth of mercury; and this amalgam in powder is mixed



with an equal weight of corrosive sublimate. The whole is then introduced into a retort, a receiver adapted, and distillation proceeded upon by a gentle heat. An insipid liquor passes over first, which is followed by a sudden eruption of white vapours, which condense into a transparent liquor, that emits a considerable quantity of vapours by mere exposure to the air. The residue in the retort, for an analysis of which we are indebted to Mr. Rouelle the younger, consists of a slight lining in the neck of the retort, which contains a small quantity of the fuming liquor, some muriate of tin, muriate of mercury, and running mercury. The bottom of the vessel contains an amalgam of tin and mercury; above which lies a muriate of tin of a grey white, solid and compact, and which may be volatilized by a strong heat.

The nitro-muriatic acid dissolves tin with vehemence: a violent heat is excited; and it frequently happens that a magma is obtained resembling pitch, which becomes harder in process of time. This happens when the very concentrated acid has dissolved too much of the metal; and these inconveniences may be obviated by adding water in proportion as the solution proceeds.

The solution of tin which constitutes the composition for scarlet, is made with the common aqua-fortis, prepared with saltpetre of the first boiling. This is a kind of nitro-muriatic acid, which unfortunately varies in its properties, according to the two variable proportions of muriate of soda and nitrate of potash. For this reason, the dyers are continually making complaints, either that the aqua-fortis precipitates, which happens when it contains too small a quantity of muriatic acid; or that it affords an obscure colour, which depends on an excess of the same acid. The first inconvenience is remedied by dissolving sea salt, or sal ammoniac, in the aqua-fortis; and the second by adding saltpetre.

The most accurate proportions to make a good solvent for tin, are, two parts of nitric acid, and one of muriatic acid.

Tin is likewise soluble in the vegetable acids. Mr. Schultz, in his Dissertation *De Morte in Olla*, has demonstrated the solubility of this metal in acids. Vinegar corrodes it by a gentle heat, according to the experiments of Margraff.



Most of the tin in commerce is alloyed with various metals. That of England contains copper and arsenic artificially, according to Geoffroy; and naturally, according to the Baron Dietrich, Sage, &c. The tin of the plumbers or pewterers, called Pewter, contains several metals. The ordonnance in France permits them to add a small quantity of copper and bismuth. The first metal renders it hard; and the latter restores the brightness which would else have been impaired by the copper, and renders it more sonorous. The pewterers take upon themselves to add antimony, zinc, and lead; the antimony hardens it, the zinc renders it whiter, and the lead diminishes its value. It is a desirable circumstance to possess the means of ascertaining the nature and proportions of these alloys. We are indebted for the following processes to Messrs. Bayen and Charlard.

A. When tin contains arsenic, the solution in the muriatic acid exhibits a black powder, which consists of arsenic separated from the tin. This method is capable of rendering the two thousand and forty-second part of alloy perceptible.

B. If the tin contains copper, the muriatic acid, which attacks tin with facility, precipitates the copper in the form of a grey powder, provided there be no excess of acid, and the solution be made without heat. The copper is likewise precipitated by a plate of tin immersed in the solution.

C. Bismuth is shewn by the same process as the copper.

D. To ascertain the mixture of lead, the nitric acid must be used, which corrodes the tin, and dissolves the lead.

The pewterers have two methods of assaying this metal.

1. The assay of the stone, which consists in pouring it into a hemispherical cavity made in a calcareous stone, and terminating in a channel or groove. The workman attentively observes the phenomena of its cooling; and from these circumstances, as well as from the crackling or noise which the tail of the assay affords when bended, he judges of the purity of the metal.

2. The assay by the ball consists merely in a comparison of the weight of pure tin with that of adulterated or alloyed tin, poured into the same mould.

It cannot but be immediately perceived that these methods are very imperfect.

The various metals which are prejudicial to health, are not added to the tin in a sufficiently great proportion to produce any dangerous effects. It seems that Margraff was deceived by some foreign circumstance, when he affirmed that the tin of Morlaix contains thirty-six grains of arsenic in the half ounce; for this quantity is more than sufficient to render the metal as brittle as zinc. Messrs. Bayen and Charlard found no arsenic in the tin of Banca and of Malacca. The tin of England never contains more than three-fourths of a grain of arsenic in the ounce of metal; and supposing this to be the maximum, the daily use of tin cannot be dangerous; since a plate in which arsenic existed in this proportion, lost no more than three grains per month by constant use, which amounts to the five thousand seven hundred and sixtieth part of a grain of arsenic lost daily. The experiments which these two skilful chemists have made upon animals, by mixing arsenic in larger proportions with tin, are sufficient to remove every apprehension concerning the use of this metal.

The lead alone may be productive of dangerous consequences, because the pewterers add it in a very considerable proportion.

The combination of tin with sulphur forms aurum musivum, or mosaic gold. The process for making it which has best succeeded in my hands, is that described by the Marquis de Bulliop. It consists in forming an amalgam of eight ounces of tin and eight ounces of mercury. For this purpose, a copper mortar is heated, and mercury poured into it: and when it has acquired a certain degree of heat, the melted tin is poured in, and the mixture agitated and triturated till cold. Six ounces of sulphur, and four ounces of sal ammoniac, are then mixed; and the whole put into a matraass, which is to be placed on a sand bath, and heated to such a degree as to cause a faint ignition in the bottom of the matraass. The fire must be kept up for three hours. The aurum musivum thus obtained is usually beautiful: but if, instead of placing the matraass on the sand, it be immediately exposed upon the coals, and strongly and suddenly heated, the mixture will take fire, and a sublimate will be formed in the neck of the vessel, which consists of the most beautiful aurum musivum. .I

have obtained it by this process of a dazzling colour in large hexagonal scales.

The mercury and the sal ammoniac are not in strictness necessary to the production of aurum musivum. Eight ounces of tin dissolved in the muriatic acid, precipitated by the carbonate of soda, and mixed with four ounces of sulphur, produced the Marquis of Bullion a fine aurum musivum: but this is not capable of increasing the effects of the electrical machine, which proves that the composition owes its virtue in that respect to the mercury it contains in the proportion of six to one, when prepared in the former process. This preparation is used to give a beautiful colour to bronze, and to increase the effects of the electrical machine by rubbing the cushions.

The Baron Kienmayer has described the following amalgam, composed of two parts of mercury, one of zinc, and one of tin:—The zinc and the tin are to be fused, and mixed together with the mercury; and the mixture agitated in a wooden box, internally rubbed with chalk. The mass is then to be reduced to a fine powder; and employed in that state, or mixed with grease. The effect of this amalgam is surprizing; for by this means the power of electrical machines is inconceivably augmented.

The amalgam of tin is capable of crystallization. Mr. Sage's process consists in pouring two ounces of melted tin into a pound of mercury. After having introduced this mixture into a retort, he urged it by a violent fire for five hours on the sand bath. No mercury was disengaged; but the tin was found in a crystallized state above the mercury which had not entered into combination. The lower part of this amalgam is composed of grey brilliant crystals in square plates, thin towards their edges, having polygonal cavities between each. Every ounce of tin retains in its crystallization three ounces of mercury.

The amalgam of tin is used to silver looking-glasses. For this purpose, a leaf of tin is spread out upon a table of the size of the glass, mercury is poured upon it, and spread about with a brush. This being done, a larger quantity of mercury is poured upon the tin, so as to form a covering of more than one line in thickness. The glass is slid upon this covering, by presenting one of its edges;



taking care at the same time that its surface shall be beneath the level of the mercury, in order that the impurities which might hinder a perfect contact may be driven before it. The plate of glass is then loaded with weights equally distributed over its whole surface; by which means all the excess of mercury is pressed out, and flows away through channels made in the edges of the table. The air being driven out from between the amalgam of tin and the glass by this strong compression, serves greatly to render the amalgam adherent. Several days are required to elapse before it be sufficiently dry to admit of removing the glass.

Tin alloyed with copper forms bronze, or bell-metal. Seven parts of bismuth, five of lead, and three of tin, form an alloy which liquefies in boiling water.

## CHAPTER X.

### *Concerning Iron.*

IRON is the most generally diffused metal in nature. Almost every mineral substance of this globe is coloured with it; and its various alterations produce that truly astonishing variety of colours which are comprehended between the blue and the deepest red. This metal likewise exists in the vegetable kingdom, where it constitutes an almost inseparable principle. It even appears to be one of the products of organization, or vegetation; for it is found in vegetables which are supported merely by air or water. It is indeed contrary to sound philosophy to suppose that all the iron with which earths are impregnated, must arise from the wearing of ploughshares: for, not to mention that the plough has not passed every where, we see iron daily formed in vegetables. There is no reason to fear that the metal should on this account become too abundant; because it is continually destroyed by passing to the state of oxide.

If, on the other hand, we cast our attention towards the infinite number of uses to which this metal is applied in society, we shall perceive that it is perhaps the most essential to be known, because it is the most diffused, the most useful, and the most employed.



This metal is of a white livid colour, inclining to grey, obedient to the magnet, and gives fire with quartz; which last circumstance is attributed to the fusion and rapid combustion of particles of the metal detached by the stroke. It is the lightest of all metals except tin. One cubic foot of forged iron weighs five hundred and forty-five pounds. The specific gravity of fused iron is 7,2070.—See Briffon.

Iron is very hard, susceptible of a fine polish, and very difficult of fusion. It may be drawn into very fine wire, of which the strings of the harpsichord are made. It becomes hard by hammering, without heat; but when assisted by heat, it may be hammered into every imaginable form.

Iron is universally dispersed; but, by common consent, those places, or matrices, in which the iron is sufficiently abundant to be wrought with profit, are called Iron Mines; or Ores.

Iron is found native, without mixture, in several places. We shall not here mention those ridiculous assertions, which have no other merit than that of having been authorized by the suffrages of certain celebrated men.—“ALBERTUS MAGNUS decidisse cœlum, imbre, massam ferri centum librarum. *Péternannus*, magnâ tempestate, cum projectu multorum lapidum, cœlo molem ferri decidisse, quæ in longitudine sexdecim, in latitudine quindecim in crassitie duos, pedes habuerit:” that is, of the weight of forty-eight thousand pounds, and containing four hundred and eighty cubic feet.—Becher suppl. in Phys. Subter. cap. iii. p. 599.

We are indebted to Lehman for a description of a piece of native iron possessed by Margraff, which came from Eibenstock in Saxony. The grain was distinguishable on both sides.

Henckel possessed a small piece incrustated with a yellow earth; and the cabinet of the Royal School of mines possesses one which is covered with spathose iron ore. Adanson and Wallerius affirm that it is found in Senegal; and Rouelle received a piece from thence which was very malleable. Simon Pallas speaks of a mass of native iron found near the great river Jenesei in Siberia. This iron is a very spongy, very pure, perfectly flexible, and proper to be formed into instruments by a moderate fire. It is naturally incrustated with a kind of varnish which preserves it from rust.

Mr. Macquart doubts the legitimacy of the native iron, described by Pallas: he thinks that it may be considered as fused iron. Mr. De Morveau does not believe in the existence of native iron.

Though some doubts may be raised concerning the legitimacy of these pieces, and there may be reasons to consider some of them as consequences of the action of fire, we cannot however refuse to admit of the existence of native iron, after the depositions, facts, and attestations which present themselves on all sides in support of this truth.

Iron, slowly cooled, crystallizes in octahedrons almost always implanted one in the other. We are indebted to Mr. Grignon for this observation. I am in possession of a piece of iron entirely covered with small tetrahedral, flat, and truncated pyramids. Some of the pyramids have a base of one line in breadth. It comes from the frontiers of the Comté de Foix. This iron is very seldom found unaltered by foreign admixtures; but I think we may consider all the iron ores which are attracted by the magnet, as containing the native metal, dispersed in some gangue: and we shall attend to these species before we treat of the oxides and martial salts.

## ARTICLE I.

Concerning Iron Ores which are attracted by the Magnet.

1. The octahedral iron ore.—This ore has the form of octahedrons, isolated, and dispersed in a gangue of schistus, or calcareous stone. The crystals are grey, very regular in their form, and strongly bedded in the stone. Their size is from half a line to six or seven in diameter. Corsica and Sweden afford this kind.

Mr. Sage observes that octahedral crystals of iron are sometimes found in the finest white marble of Carara. The black ferruginous sand which accompanies the hyacinths in the brook of Espailly, is an octahedral iron ore, obedient to the magnet.

2. Iron ore in small plates or scales.—The small plates or scales which are attracted by the magnet, and are found in most rivers which contain gold, are an iron ore, nearly in the metallic state. This sand forms the residue which is left after the precious metal has been taken up by amal-

gamation. It is mixed with fragments of quartz, garnets, &c. I found a large quantity in the sand of the river of Ceze: it was also sent me from the neighbourhood of Nantz. I have received some likewise from Spain; and this sand has afforded me certain phenomena which appear to entitle it to a particular rank among the metals. Acids dissolve it by the assistance of heat; and always without effervescence, or the disengagement of gas. It communicates the same colour to the nitro-muriatic acid as platina does. It is indecomposable by heat, either in the open fire, or in open vessels. I have endeavoured to reduce it by all the known fluxes, but in vain. It precipitates in the flux, mixes with it, and recovers its form and magnetic virtue by pulverizing the mass. It possesses several characters of the siderotete, or phosphate of iron.

3. Iron dispersed in stones renders them obedient to the magnet. The ophites, the serpentines, the micas, the pot-stones, and several marbles, are in this situation. Iron disseminated in a gangue of quartz, or very hard jasper, forms emery, which on account of its hardness is used to grind and polish glass. It comes to us from Jersey and Guernsey, where it is plentifully found.

The magnet itself is nothing else but the iron we speak of, modified in such a manner as to afford a passage to the magnetic fluid, and to exhibit the known phenomena. The magnet is sometimes found in a regular form. Mr. Sage affirms that he possesses a small piece of magnet from St. Domingo, on which octahedrons are distinguishable. We likewise read, in the General History of Voyages, that at twenty leagues from Solikamskai in Siberia magnets are found of a cubical form and greenish colour, of a lively brilliant appearance, which are reducible into glittering scales by pulverizing.

The magnet varies in its quantity of metal. Those of Sweden and Siberia are very rich in iron; but the magnetic force is not in proportion to the iron they contain.

There is reason to think that the magnetic agent is a modification of the electric power. 1. Iron which remains a long time in an elevated position becomes magnetic. 2. Instruments of iron struck with lightning are usually mag-

netized. 3. Two pieces of iron may be magnetized by rubbing them against each other in the same direction. 4. Black iron ores are found in Sweden which are attracted by the magnet, and whose metallic particles are sometimes so weakly connected together that they are reducible into powder. We have several species of these ores in Languedoc.

This species is in general very rich, and affords near eighty pounds of iron per quintal.

5. Iron appears to exist in the metallic state in some other species, such as the specular iron ore. But the metallic state is less evident and characteristic, the metallic qualities being more changed; and these ores are less attracted by the magnet.

These iron ores frequently exhibit metallic plates of a brilliancy equal to that of steel, and unalterable in the air. The ore of Mont d'Or, that of Framont in the principality of Salm, and those of the mountains of Vosges, have afforded us very curious specimens. These plates are sometimes hexagonal, formed by two hexahedral pyramids truncated near their base.

The specular iron ore of Framont afforded Mr. Sage fifty-two pounds of iron in the quintal: the iron is very ductile, and acquires much fibre.

The celebrated iron ore of the island of Elbe is of this kind, but it has not the plated form. Its crystals are lenticular, with brilliant facets, which are dodecahedrons with triangular planes. These beautiful groupes of crystals are sometimes shaded with the most lively colours. White clay, rock crystal, cupreous pyrites, &c. are found among them.

The Lucquese work this ore in the Catalan method, by stratifying charcoal and the ore, one layer over the other. The fire is kept up by good bellows; and when all the coal is consumed, the iron is found collected together in a mass, which is carried to the hammer.

The eisenman is a scaly specular ore. When it is rubbed, brilliant particles are detached from it; which has caused the miners of Dauphiny to give it the name of Luisard.

The eisenram is an iron ore of a brilliant red colour, which contains plumbago and iron.



## ARTICLE II.

Concerning Sulphureous Iron Ores, or the Sulphures of Iron.

The union or combination of iron and sulphur forms the sulphureous iron ore, martial pyrites, sulphure of iron, &c. These sulphures are very abundant, and are evidently formed by the decomposition of vegetables. I have several times found pieces of wood buried in the earth perfectly incrustated with pyrites. The effect of subterraneous fires is owing only to the mixture of these sulphures with the remains of vegetables. Those species of coal which effloresce in the air, owe their decomposition only to the pyrites with which they are penetrated. It is likewise to the decomposition of the pyrites that we must refer the heat of most mineral waters. The sulphure of iron sometimes crystallizes in cubes, and often in octahedrons. The union of a number of octahedral pyramids with their points towards a common centre, forms the globular pyrites.

When the sulphur is dissipated, it sometimes happens that the pyrites loses neither its form nor its weight. It then becomes brown, is attracted by the magnet, and is called the Brown or Hepatic Iron Ore.—See De Lisle.

But the decomposition of pyrites most commonly produces the sulphuric acid, which seizes the iron, dissolves it, and forms an efflorescence on the surface. Advantage has even been taken of this property of the pyrites to establish manufactories of sulphate of iron, or copperas. The two valuable establishments which have been made of this kind, in the vicinity of Alais, work certain strata of a hard ponderous pyrites. These are formed into heaps upon areas, where the ground is slightly inclined. The efflorescence is accelerated by watering the pyrites, grossly broken, with water. This fluid dissolves all the salt which is formed, and carries it into reservoirs, where the solution suffers all the foreign matters it may contain to subside. It is left at rest in these reservoirs, in which the sun produces a slight concentration of the fluid; and the concluding evaporation is made in leaden cauldrons, with the addition of old iron, to saturate the acid with as much of that metal as possible. The crystallization is performed in basins, in which pieces of wood are disposed to assist the formation of crystals.

These two manufactories in Languedoc are capable, in their present state, of furnishing upwards of forty thousand quintals of copperas, if the demand required it.

In order to facilitate the vitriolization, it is necessary to give access to the air, because the concurrence of this element is necessary to form the sulphuric acid.

The sulphate of iron crystallizes in rhomboids.

It effloresces in the air, and gradually loses its fine green colour by the dissipation of its water of crystallization.

If the sulphate of iron be exposed to heat, it liquefies, boils, becomes thick, and is reduced into powder. This powder, mixed with pulverized nut galls, forms a dry ink, which several persons sell as a secret, and which requires only the addition of water to render it fit for use.

The same powder, urged by a stronger heat, suffers its acids to escape; after which there remains only a martial earth, or metallic oxide, known by the name of Colcothar.

I attribute the formation of all the yellow or red earths, commonly called ochres, to a similar decomposition of the pyrites. The heat produced by the decomposition of the pyrites has determined the respective colours of these earths; and they may be caused to pass artificially through these various shades, by treating them with various degrees of fire. I have discovered, in the diocese of Uzes, banks of ochre of such uncommon fineness, and so very pure, that calcination converts it into a brown red, superior to every thing before known in trade. The manufactory which has been established under my care, has acquired all the celebrity which the superiority of its products could not but necessarily afford it. My experiments on these ochres, and the advantages which they may afford to the arts, may be seen in the work which I have published on this subject, printed for Didot the elder, at Paris.

I likewise found at Mas-Dieu, near Alais, a stratum of red ochre of so beautiful a colour, that it could scarcely be imitated.

### ARTICLE III.

Concerning the *Spathose Iron Ores*, or Carbonates of Iron.

The carbonic acid is sometimes combined with iron in ores; and the resemblance between this iron and spar, has procured it the name of the *Spathose Iron Ore*.

The formation of this ore appears to be owing to the mutual decomposition of the carbonates of lime, and the sulphates of iron. A solution of copperas, in which calcareous spar was suffered to remain, produced this ore, according to the experiments of Mr. Sage.

Bergmann obtained from the ores of this kind, which he analysed, thirty-eight ounces of the oxide of iron, twenty-four ounces of the oxide of manganese, and fifty ounces of calcareous earth. It appears therefore that this ore contains two metals united by a calcareous cement, which crystallizes always in its own form, as we find in the lapis calaminaris, the calcareous grit, &c.

The spathose iron ores are wrought at Cascastel, in the diocese of Narbonne, at Bendorf on the banks of the Rhine, at Eisenartz in Styria, &c.

#### ARTICLE IV.

Concerning the Bog Ores of Iron, or Argillaceous Iron Ores.

These ores consist merely of a martial oxide, in a state of greater or less purity, mixed with earthy substances of the nature of clays.

They appear to have been deposited by water; and are usually disposed in strata, which are frequently marked out, and as it were separated, into small prisms, whose formation arises simply from the shrinking of the clay.

1. The eagle-stone, or ætites, ought to be ranked among the bog ores of iron. They are geodes of a round or oval form, having a hard external covering, while the cavity includes a detached nodule; and the noise produced by shaking one of these stones, arises from the nodule being at liberty to move within the stone.

The name of eagle-stone has arisen from a notion, formerly entertained, that eagles placed it in their nests to facilitate the laying of their eggs; and wonderful powers of rendering labours safe and easy, were attributed to it in the times of superstition.

2. We are acquainted with an iron ore in round pieces, resembling bullets, of several lines in diameter, which ought to be considered as a variety of the preceding. An ore of this kind was begun to be wrought at Fontanez,

near Sommieres ; and we find a considerable quantity of these metallic globules among our red earths in the neighbourhood of Montpellier.

3. The purest oxide of iron, worn and carried along by waters, and afterward, deposited, forms strata of various appearances and colours. These are called hæmatites.

The colours arise from the various degrees of alteration in the oxide. They vary from yellow to the deepest red. The red hæmatites is used in the arts to burnish gold or silver. It is cut into long pieces, which when polished are known by the name of burnishers. This blood-stone is sometimes soft enough to be used instead of a crayon for drawing.

Its figure is likewise subject to prodigious variation. It often appears as if composed of small prisms applied one against the other, in which case it is called the fibrous hæmatites. In other specimens it is tuberculated. It is very frequently found in compact irregular masses, such as those of the ores of the county of Foix. This must naturally exhibit the same variety of forms as the calcareous stalactites, because its mode of formation is nearly the same.

#### ARTICLE V.

Concerning Native Prussian Blue, or the Prussiate of Iron.

Beccer speaks of a blue earth found at Turinge. Hencel informs us that a blue martial earth is found at Schnee-burg and at Eibenstock. Cronstedt has described a native Prussian blue: Mr. Sage found it in the turf of Picardy. It is likewise found in Scotland, in Siberia, &c, and I possess a sulphure of iron in a state of decomposition, which exhibits a true prussiate of iron upon one of its surfaces.

#### ARTICLE VI.

Concerning Plumbago, or the Carbure of Iron.

The name of Plumbago is at present confined to that shining substance of a blackish blue colour, which is used to make the pencils called black-lead pencils. It has a greasy feel, exhibits a tuberculated fracture, soils the hands, and leaves a black trace upon paper.

Plumbago is found in many places; that of commerce is brought to us from Germany. We receive it likewise from Spain, from America, and from England. It is also



found in France. This mineral is almost always disposed in separate masses in the bowels of the earth; and it is probably on account of this form, that the ancients denoted it by the words *Glebæ Plumbariæ*.

The plumbago of England differs from the other specimens in its texture, which is much finer, and of a greater degree of brilliancy. The English do not take a larger quantity out of the mine than the market demands, in which they are careful to keep up the price.

The most plentiful mine is in the county of Cumberland.

The plumbago of Spain is always accompanied with pyrites, which effloresce on the surface of the pieces; either in small crystals, similar to those of the sulphate of iron; or in a kind of silky vegetation, analogous to that of plume alum. It is dug up in the neighbourhood of the town of Ronda, at the distance of four leagues from the Mediterranean sea. It is the worst kind which comes to market, and is used only to give a shining black colour to iron utensils.

The American plumbago, which Mr. Woulfe procured for Mr. Pelletier, breaks easily, and exhibits small quartzose grains in its internal part, as well as slight traces of a whitish clay. It is found in separate masses; and its texture appears to consist of the union of an infinity of small scaly parts, which at first sight might cause it to be taken for molybdena.

France likewise possesses plumbago, and the chevalier Lamanon observed it in Upper Provence. The mine is situated near Col. de Bleoux. The black lead is found between two strata of clay, not more than a few lines in thickness. It forms a stratum of four inches thick; or rather the stratum consists of separate masses, which are sometimes several feet in length. It is accompanied by a vein of pyrites. The inhabitants of Bleoux sell this product at Marseilles at about fifteen livres per quintal. Mr. De la Peyrouse found plumbago with tourmalines in the county of Foix, and Mr. Darcet brought it from the Pyrenean Mountains.

Plumbago is indestructible by heat without the presence of air. Mr. Pelletier exposed it to distillation, in the pneumato-chemical apparatus, by a violent fire during six hours, without the plumbago having lost weight, or suffered any

other change. He exposed two hundred grains in a well-closed porcelain crucible to the fire of the manufactory at Seves, and it lost only ten grains. But when it is calcined with the concurrence of air, it then burns, and leaves but a small quantity of residue. Messrs. Quist, Gahn, and Hielm observed that one hundred grains, treated under a muffle in a shallow vessel, left only ten grains of oxide of iron. Mr. Fabroni dissipated the whole of a portion of plumbago exposed under the muffle. This calcination is a slow combustion, which is facilitated by causing the matter to present a large surface, and agitating it from time to time.

If one part of plumbago, and two of very caustic dry alkali, be heated in a retort with the pneumato-chemical apparatus, the alkali becomes effervescent, hydrogenous gas is obtained, and the plumbago disappears. This beautiful experiment proves that the small quantity of water contained in the salt is decomposed; and that its oxigene, by combining with the carbone of the plumbago, forms the carbonic acid. The experiment published by Scheele has been repeated and confirmed by Mr. Pelletier.

The sulphuric acid does not act upon plumbago, according to Scheele. Mr. Pelletier has observed that one hundred grains of plumbago, and four ounces of oil of vitriol, being digested in the cold for several months, the acid acquired a green colour, and the property of congealing by a very slight degree of cold. The sulphuric acid distilled from plumbago, passes to the state of the sulphureous acid; at the same time that carbonic acid is obtained, and an oxide of iron is left in the retort.

The nitric acid has no action upon plumbago unless it be impure. Eight ounces of nitric acid, distilled from half a gros of purified plumbago, neither altered its shining appearance, nor deprived it of its unctuous feel.

The muriatic acid dissolves the iron and the clay which contaminate native plumbago. Messrs. Berthollet and Scheele availed themselves of this method to purify it. The liquor being decanted after digestion upon the plumbago, the residue is then washed, and submitted to distillation to separate the sulphur. The muriatic acid alone has no action upon plumbago, but the oxygenated muriatic acid dissolves it; the result being a true combustion effected

by the oxigene of the acid, and the carbone of the plumbago.

If ten parts of the nitrate of pot-ash be fused in a crucible, and one part of plumbago be thrown thereon by a little at a time, the salt will deflagrate, and the plumbago will be destroyed. The matter which remains in the crucible consists of very effervescent alkali, and a small portion of martial ochre.

If plumbago be distilled with muriate of ammoniac, the muriate sublimes, coloured by the iron.

All these facts prove that plumbago is a peculiar combustible substance, a true charcoal combined with a martial basis. Plumbago is more common than is imagined. The brilliant charcoal of certain vegetable substances, more especially when formed by distillation in close vessels, possesses all the characters of plumbago. The charcoal of animal substances possesses characters still more peculiarly resembling it. Like it they are difficult to incinerate, they leave the same impression on the hands and upon paper; they likewise contain iron, and become converted into carbonic acid by combustion. When animal substances are distilled by a strong fire, a very fine powder sublimes, which attaches itself to the inner part of the neck of the retort. This substance may be made into excellent black-lead pencils, as I myself have proved.

Carbone may be formed in the earth by the decomposition of wood together with pyrites; but the origin of plumbago appears to me to be principally owing to the ligneous, and truly indecomposable, part of the wood, which resists the destructive action of water in its decomposition of vegetable substances. This ligneous substance disengaged from the other principles, must form peculiar depositions and strata; and Mr. Fabroni has assured me that the formation of plumbago in water is a common phenomenon, of which he had several times been a witness. This chemist, by his letter of the thirtieth of January 1787, informs me that, in the dominions of the king of Naples, there are wells dug expressly for the purpose of collecting an acidulous water, at the bottom of which wells a quantity of plumbago is collected every six months.

He supposes that the black mud which is found beneath the pavement of Paris is plumbago formed in the humid way.

There are likewise districts in Tuscany where plumbago is formed in the humid way.

This substance is of considerable use in the arts. It has been at all times applied to the purpose of making pencils, the most esteemed of which are those which come from England. They are made at Keswick in the county of Cumberland. The piece of plumbago is sawed into very thin plates. The edge of one of these plates is fitted into a groove struck in a wooden cylinder; and the thin plate of plumbago is then cut off in such a manner that the cavity of the small cylinder remains perfectly filled.

The dust of plumbago is used to lubricate certain instruments; and it is likewise made into pencils of an inferior quality, by kneading it up with mucilage, or by fusing it with sulphur. The fraud may easily be discovered by the assistance of fire, which burns the sulphur; or by means of water, which dissolves the mucilage.

Plumbago is likewise used to defend iron from rust. The hearths and plates of chimneys, and other similar utensils, which appear very bright owe their colour to plumbago. Homberg has communicated a process, in the year 1699, in which plumbago is applied to this use. Eight pounds of hogs-lard are melted with a small quantity of water, with the addition of four ounces of camphor. When this last is fused, the mixture is taken from the fire; and, while it is yet hot, a small quantity of plumbago is added, to give it a leaden colour. When this is to be applied, the utensils must be heated to such a degree, that the hand can scarcely be applied to them. In this state the composition must be rubbed on them, and afterwards wiped when the piece is dry.

Those who prepare small shot, make use of black lead to polish and glaze it: the shot is rolled or agitated together with a quantity of plumbago. Plumbago is likewise used to make razor strops. When kneaded up with clay, it forms excellent crucibles, which we receive from Passaw in Saxony. One part of plumbago, three of argillaceous



earth, and a small quantity of cows' dung very finely chopped, form an excellent lute for retorts. Mr. Pelletier has used it with great advantage. This lute is exceedingly refractory; and the glass will melt without the covering changing its form.

To make the affay of an iron ore, I find the following flux very advantageous:—I mix four hundred grains of calcined borax, forty grains of flacked lime, two hundred grains of nitrate, and two hundred of the ore to be assayed. I pulverize this mixture and place it in a lined crucible, which I cover. The heat of a forge furnace is sufficient to effect the reduction. In the space of half an hour, the button of metal is found deposited at the bottom of the vitrified flux.

The process for working iron mines varies according to the nature of the ore. The metal is sometimes so little altered, and so abundant, that nothing more is necessary than to mix it with the coal, and fuse it. This simple and economical process forms the basis of the Catalan method, which may be employed in treating the spathose iron ores, those of Elbe, the hæmatites, and other rich and pure ores. But it cannot be applied to such as contain much foreign matter capable of becoming converted into slag. For this reason, the experiments made in the county of Foix on the ores of various countries, and various qualities, have not succeeded. On this head, the work of Mr. De la Peyrouse, and the Memoirs of the Baron de Dietrich, may be consulted.

The furnaces in which iron is fused, are from twelve to eighteen feet in height. Their internal cavity has the form of two four-sided pyramids joined base to base. The only flux added to the ore is the calcareous stone, named (by the French) *castine*, if the ore be argillaceous; but, if the gangue be calcareous, the workmen employ argillaceous earth, which is named *herbue*.

The furnace is charged at the upper part; and the fire is excited by bellows, or hydraulic machines. The ore melts as it passes through the coal and is collected at the bottom, where it is maintained in a liquid state. At the end of every eight hours it is suffered to flow out into the mould, & hollow channel made in the sand.

Crude iron, cast in suitable moulds, forms chimney-backs, pots, cauldrons, pipes, and an infinity of utensils or vases, which could not be obtained without difficulty by forging the iron. The works which are established at Creusot in Burgundy surpass every thing which can be defined in this species of industry.

This first product is called Cast or Crude Iron. It is brittle; but may be rendered ductile by heating it again, and hammering it. For this purpose the pig iron is fused again, and stirred while in the state of fusion: after which it is carried to the forge hammer. By this treatment the iron becomes ductile, assumes a fibrous texture, and is formed into square or flat bars for the purposes of trade.

Iron is likewise capable of a degree of superiority, which is given to it by placing it in contact with coaly substances, and softening it to such a degree that these may penetrate into its texture. It is then known by the name of Steel. We are indebted to Mr. Jars for very interesting accounts of the steel manufactories in England. The manufactory established at Amboise is not inferior to those of England, as was ascertained by comparative experiments made upon the products of the several manufactories, at Luxemburg, on Friday the 7th of September, 1786.

We may therefore divide the different states of iron into cast or crude iron, iron properly so called, and steel. It is clear that these three states are nothing more than modifications of each other; but the circumstances on which they depend, and the principle which establishes their difference, were till lately unknown.

The celebrated Bergmann has given an analysis of the various states of iron, and has drawn up the following table:

	Cast Iron.	Steel.	Iron.
Inflammable Air -	40	48	50
Plumbago -	2 - 20	0 - 50	0 - 12
Manganese -	15 - 25	15 - 25	15 - 25
Siliceous Earth -	2 - 25	0 - 60	0 - 175
Iron -	80 - 30	83 - 65	84 - 45

This celebrated chemist has confirmed by his results the conclusion of Reaumur, who always considered steel as an intermediate state between crude and malleable iron.

We are indebted to three French chemists, Messrs. Monge, Vandermonde, and Berthollet, for a quantity of much more accurate information respecting all these states.

We may consider iron ores as natural mixtures of iron, oxigene, and various foreign substances. When an ore is wrought, the object of the operator is to clear the iron of all these matters. To effect this separation, the ore is thrown into the smelting furnaces, with different proportions of charcoal. These matters are heated together until they arrive at the hottest part where the mixture falls; and, after suffering the strong action of the fire, is precipitated in fusion, and forms a fluid mass at the bottom of the furnace. The earths and stones, nearly in a vitrified state, float above the fluid; and the oxigene, being partly driven out, remains likewise in a greater or less quantity in the crude iron. The crude iron is either white, or grey, or black. In our enquiries concerning the cause of these three kinds of iron, and their qualities, we can refer them only to the proportions of foreign principles contained in the crude iron. These principles are carbone and oxigene.

1. Crude iron contains carbone. The ladles which are used to agitate, take up, and pour out this melted metal, become covered with a coating of plumbago, which contains nine-tenths of carbone: and cast iron, strongly heated in contact with the coal, suffers a part to escape or exude from its surface when it is slowly cooled. Crude iron emits sparks when it is heated; the acids which dissolve it always leave a residue which is purely carbonaceous. The hydrogenous gas, which is obtained by treating these irons with acids, always affords the carbonic acid by combustion.

2. Crude iron contains oxigene. Several mineralogists attribute the fragility and brilliancy of crude iron to its still containing iron in the state of oxide. This opinion, which is generally adopted, supposes the existence of oxigene. Crude iron, urged by a violent heat in close vessels, affords the carbonic acid, and passes to the state of soft iron; because its oxigene then unites to the carbonaceous principle, and constitutes the carbonic acid, which exhales, and clears the crude iron from the two principles which altered its quality.

Oxigene and carbone exist therefore in crude iron, but they may exist in three different states—1. A large quantity of carbone, and a small quantity of oxigene. 2. An exact proportion between these two principles. 3. Much oxigene, and a small quantity of carbone.—Now we find these three states in the three kinds of crude iron which we have distinguished, as is proved by analysis; and, as we may judge by the secondary processes, to correct these imperfections, or to convert crude iron to the malleable state.

1. In the first case, that iron which contains an excess of carbone is agitated or stirred as it flows out. It is kept a long time exposed to the action of the bellows, and the smallest possible quantity of charcoal is made use of. We see that in this process the properest methods are used to facilitate the combustion of this excess of the carbonaceous principle.

2. In the second case, that kind of iron in which the principles exist in accurate proportions, requires only the action of heat to unite and volatilize the two foreign principles. The crude iron is put into a state of ebullition by the disengagement of the acid which is formed, and exhales.

3. In the third kind, or that which contains oxigene in excess, the bellows are urged less violently; and the metal is penetrated with coal in order to combine with the oxigene. Here therefore we see theory and practice go together. The former explains the usual manipulations, and affords us principles in cases wherein experiment too frequently fails.

Steel is a kind of iron which contains carbone only; and its existence may be proved by all the experiments which have been mentioned as demonstrations that crude iron contains it.

Carbone may be given to iron—1. In the fusion of the ore. 2. Or, afterwards, by the cementation of iron with coaly substances.

1. In some parts of Hungary, and in the county of Feix, iron ores are wrought which contain the metal nearly in the disengaged state; and the cast iron, when duly hammered, affords iron and steel in a greater or less quantity, according to the management of the fire, the quantity of air



afforded by the tuyere, the quantity of coal made use of, and the nature of the ore. In this operation, the iron being scarcely at all calcined in the ore, becomes charged with coaly matter only, and the result is steel.

2. If the coaly principle be combined with iron in a ductile state, and deprived of all foreign matter, the combination being effected by cementation or otherwise, the iron will pass to the state of steel; and the qualities of this steel will vary according to the proportions of carbone. The purity of the iron, and the care which is taken to avoid the oxidation of the metal, establish the various kinds of steel which are met with in commerce.

The nature and the principles of steel being once admitted and established, the following facts will explain themselves.

1. Since steel contains no foreign principle but carbone, it is not surprising that it remains unchanged by a violent heat in close vessels.

2. Steel, repeatedly heated, and exposed while hot to a current of air, lose its properties, and passes again to the state of soft iron.

3. Steel kept plunged for a time in crude iron in which oxigene predominates, becomes itself converted into soft iron.

4. Soft iron kept for a time plunged in crude iron, wherein carbone predominates, becomes converted into steel.

5. Iron, by passing to the state of steel, increases in weight one hundred and seventieth part.

Ductile iron would be a very soft metal, if it were cleared of all foreign substances.

From all these facts we may conclude—1. That crude iron is a mixture of iron, carbone, and oxigene. 2. That the products of crude iron are white, grey, or black, according to the proportions of oxigene and carbone which it contains. 3. That the steel of cementation is merely a mixture of iron and carbone. 4. That steel which is over-cemented, is an iron containing too large a quantity of carbone. 5. That iron would be a very soft metal, if it were not mixed with a greater or less quantity of oxigene and carbone.

Forged iron is distinguished into soft iron, and eager or brittle iron, by us (the French) called *Rouvrain*. This last has a coarser grain than the other: it is divided into

red short iron, and cold short iron. The cause of this phenomenon is known: it arises from a phosphate of iron, which was discovered by Bergmann. This celebrated chemist constantly observed a precipitate to be formed in the solutions of cold short iron in the sulphuric acid. It was a white powder, which he called Siderite, and at first supposed to be a peculiar metal; but Mr. Meyer of Stetin has proved that it is a true phosphate of iron.

Soft iron does not afford it. All the irons of Champagne afford about a dram, or gros, in the pound of iron.

In order to obtain siderite, it is necessary that the solution should be saturated by a gentle heat on the sand bath. If the solution be made too quickly, the siderite is then mixed with ochre, which alters its purity and whiteness.

A precipitate is formed, which takes place so much the more speedily, as the solution is more diluted with water each time after filtration. The precipitate is formed in the first three or four days; a second is obtained towards the sixth day; and that which afterwards falls down is mixed with ochre.

Siderite may likewise be obtained by dissolving iron in the nitric acid, and evaporation to dryness. The iron is oxidized by this first operation. More nitric acid being poured on this residue, dissolves only the siderite, without touching the oxide of iron. A second evaporation must then be made; and the residue must be diluted with water, to evaporate the last portions of nitric acid: and that which remains is siderite. It is soluble in the sulphuric, nitric, and muriatic acids, from which it may be precipitated by pouring into the solution as much alkali as is necessary to saturate the acid solvent. If the alkali be added in excess, ochre is then precipitated; and the result is a phosphate, and a salt arising from the union of the acid made use of and the alkali which has served for the precipitation.

The fixed and volatile alkalis, and lime water, decompose siderite. It is likewise decomposed by projecting it upon fused nitre.

When it has been precipitated by ammoniac, crystals may be obtained by evaporation, which when treated with powder of charcoal afford phosphorus. The ochreous precipitate affords iron by reduction; it is therefore a com-

bination of the phosphoric acid and iron. Every solution of iron is precipitated in the form of siderite by the phosphoric acid.

The effect of the tempering of iron likewise deserves the attention of the chemist. I am of opinion that the hardness and brilliancy which iron acquires by this operation, arises from its integrant parts, which are separated by the heat, being kept and left at a certain distance from each other by the sudden cold, which drives out the heat, without bringing the constituent principles of the mass together. The iron is then more brittle, because the affinity of aggregation is less.

Iron is easily oxidized. A bar of iron which is heated a long time in the forge furnace, becomes oxidized at its surface; and the coatings of metal which pass to the state of oxide, are separated from the mass in the form of scales. The most degraded and the most altered metal, in the state when it is no longer attracted by the magnet, forms an oxide of a reddish brown colour, known by the name of Astringent Saffron of Mars, or the Brown Oxide of Iron.

The colour of this oxide varies according to its degree of oxidation. It is yellow, poppy-colour, or red; and is easily reduced into a black powder, when heated with coaly matters.

The combined action of air and water constitutes a martial oxide, known by the name of Aperitive Saffron of Mars. This composition is produced by the combination of oxygenous gas and carbonic gas with the iron. The exposition of the iron to a humid atmosphere rusts it speedily, and causes it to pass to the state of aperitive saffron of Mars. This preparation is a true carbonate of iron.

Water likewise acts upon iron. If iron filings be put into this liquid, and be agitated from time to time, the iron becomes divided, and blackens; and by decanting the turbid water, a black powder is deposited, which is called the Martial *Æthiops* of Lemery, or the Black Oxide of Iron. It is a commencement of calcination effected by the air contained in the water; but more especially by the decomposition of the water itself.

The fixed and volatile alkalis, in the fluid state, being digested upon iron, oxide a slight portion, which falls down in the form of *æthiops*.

All acids act more or less upon iron.

1. The concentrated sulphuric acid is decomposed by boiling upon this metal. If the mixture be distilled to dryness, the retort is found to contain sublimed sulphur, and a white mass, partly soluble in water, but incapable of crystallization.

But if the diluted sulphuric acid be poured upon iron, a considerable effervescence arises in consequence of the disengagement of hydrogenous gas. In this operation, the water is decomposed, its oxygen is employed to calcine the metal, while the hydrogen is disengaged; and the acid acts upon and dissolves the metal without being decomposed. This solution, when concentrated by evaporation, affords the sulphate of iron, which we have already treated of.

2. The nitric acid is decomposed rapidly upon iron. The solution is of a red brown colour, and suffers the oxide of iron to fall down at the expiration of a certain time. If new iron be plunged in this solution, the acid dissolves it, and lets fall the oxide which it held in solution.

If the solutions be concentrated, martial ochre of a red brown colour falls down. If the concentration be carried still further, a reddish jelly is formed, which is partially soluble in water.

Iron precipitated from its solution by the carbonate of pot-ash, is easily dissolved by the superabundant alkali, and forms the martial alkaline tincture of Stahl.

Mr. Maret has proposed to precipitate the iron by the caustic alkali, to make the æthiops immediately. Mr. Darcet, in rendering an account of the process of Mr. Maret to the Royal Society of medicine, has proposed that of Mr. Crohare, which consists in boiling upon the iron water acidulated with the muriatic acid.

Mr. De Fourcroy made a course of experiments upon the martial precipitates, which throws much light upon the causes of the astonishing varieties observed in them. He has proved that the whole depends either on the nature of the acid, or the manner of operating at the time of making these precipitates, or the quality of the precipitant.

3. The diluted muriatic acid attacks iron with vehemence. Hydrogenous gas is disengaged, which arises from the decomposition of the water. If the solution be concen-



trated, and left to cool when it is of the thickness of syrup, a magma is formed; thin, flattened crystals are perceived, which are very deliquescent. The muriate of iron, distilled in a retort by the Duke d'Ayen, exhibited very singular phenomena. The first product was an acid phlegm. At a stronger heat, a non-deliquescent muriate of iron sublimed, at the same time that very transparent crystals rose to the roof of the retort, in the form of the blades of razors, which decomposed the light in the same manner as the best prisms. At the bottom of the retort there remained a styptic deliquescent salt, of a brilliant colour, and a foliated appearance, which exactly resembled the large plated talc, improperly called Muscovy Glass. This last salt exposed to a violent heat, afforded a sublimate more astonishing than the former products. It was an opaque substance, truly metallic, which exhibited sections of hexahedral prisms, polished like steel. It was iron reduced, and sublimed.

4. It was long since known that iron is precipitated from its solutions by vegetable astringent substances; and the black dyes, and the fabrication of ink, are founded on this known fact. But it was not till lately that an acid has been proved to exist in these substances, which combined with the iron, and which may be obtained from all these astringent vegetables, either by simple distillation, or by mere digestion in cold water. The most simple process is the following:

Infuse one pound of powder of nut-galls in  $2\frac{1}{2}$  pints of pure water. Leave the mixture together for four days, frequently shaking the infusion. Then filter, and leave the fluid in a vessel simply covered with blotting paper. The liquid becomes covered with a thick pellicle of mouldiness, and a precipitate falls down in proportion as the infusion evaporates. These precipitates collected, and dissolved in boiling water, form a liquor of a brown yellow colour, which, evaporated by a gentle heat, deposits—1. A precipitate which resembles fine sand. 2. Crystals disposed in the form of a star. This salt is grey; and it is impossible to obtain it of a whiter colour by any repetition of solutions and crystallizations.

It is an acid which effervesces with chalk, and reddens the infusion of turnsole.

Half an ounce of this salt is soluble in an ounce and a half of boiling water, or twelve ounces of cold water.

Boiling spirit of wine dissolves its own weight of this acid; but cold spirit dissolves only one-fourth.

This salt is inflammable in the fire. It melts, and leaves a coal of difficult incineration.

When this acid is distilled in a retort, it becomes at first fluid, gives out an acid phlegm, but no oil; and, towards the end, a white sublimate rises, which attaches itself to the neck of the retort, and remains fluid as long as it is hot, but afterwards crystallizes. Much coal is found in the retort. The sublimate has nearly the taste and smell of acid of benzoin, is as soluble in water as in spirit of wine, reddens the infusion of turnsole, and precipitates metallic solutions with their different colours, and iron black.

The solution of the salt of the nut-gall, poured into a solution of gold, renders it of a dark green; and precipitates a brown powder, which is gold revived.

The solution of silver becomes brown; and at length deposits a grey powder, which is revived silver.

The solution of mercury is precipitated of a yellow orange colour.

The solution of copper affords a brown precipitate.

The solution of iron becomes black.

The solution of the acetite of lead is precipitated white.

This salt is changed into the oxalic acid, if the nitric acid be distilled from it.

The basis of ink consists of a solution of iron by the gallic acid. To make good ink, take one pound of nut-galls, six ounces of gum arabic, and six ounces of green copperas, with four pints of common water. The nut-galls must be bruised, and infused for four hours without boiling. The pounded gum must be first added, and suffered to dissolve; and, lastly, the copperas, which immediately converts the fluid to a black colour. Lewis, of the Royal Society of London, made many researches on this subject; but he always returns to the forementioned substances. Powdered sugar is sometimes added, to render the ink shining.

5. The vegetable acid likewise dissolves iron with facility. It is this which holds the metal suspended in vegetables; and it may be precipitated from wine in the form of æthiops, by the means of alkalis.

Cream of tartar, or the acidulous tartrate of pot-ash, likewise dissolves iron; and the various degrees of concentration of this solution forms the soluble martial tartar, the aperitive extract of Mars, and the balls of Nancy.

7. The solution of iron, by the oxalic acid, affords prismatic crystals of a greenish yellow colour, and a somewhat astringent taste, soluble in water, and efflorescing by heat.

8. Iron, dissolved by the prussic acid, forms Prussian blue, or the prussiate of iron.

A singular mistake gave rise to the discovery of this substance. Diesbach, a chemist of Berlin, being desirous of precipitating a decoction of cochineal with fixed alkali, borrowed of Dippel an alkali upon which he had several times distilled animal oil; and as the decoction of the cochineal contained sulphate of iron, the liquor immediately afforded a beautiful blue. The experiment being repeated was followed with similar results; and this colour became an object of commerce, under the name of Prussian Blue.

Prussian blue was announced in the Memoirs of the Academy of Berlin in the year 1710, but without any account of the process, which was kept a secret until other chemists discovered it. The process was rendered public in the year 1724, in the Philosophical Transactions, by Woodward; who declared that he had received it from one of his friends in Germany.

To make Prussian blue, four ounces of alkali are mixed with the same weight of dried bullocks blood and the mixture exposed in a crucible, which is covered in order to stifle the flame; the fire is kept up until the mixture is converted into a red-hot coal. This charcoal is thrown into water which is afterwards filtered, and concentrated by evaporation. The liquor is known by the name of the Phlogisticated Alkali. On the other hand, two ounces of the sulphate of iron and four ounces of the sulphate of alumine are dissolved in a pint of water. The two solutions are mixed, and a blueish deposition falls down, which is rendered still more intensely blue by washing it with muriatic acid.

Such is the process used in chemical laboratories; but in the works in the large way another method is followed. Equal parts of the raspings of horns, clippings of skins, or other animal substances, are taken and converted into charcoal. Ten pounds of this coal are mixed with thirty pounds of pot-ash, and the mixture is calcined in an iron vessel. After twelve hours ignition, the mixture acquires the form of a soft paste, which is poured out into vessels of water. The water is then filtered; and the solution mixed with another, consisting of three parts of alum, and one of sulphate of iron.

I have likewise made Prussian blue by calcining and burning in the same vessel equal parts of the shavings of horns and tartar. I received the animal oil and the ammoniac, afforded by the calcination of these substances in large casks, which communicated with each other, and formed an apparatus after the manner of Woulfe.

It has likewise been observed that the tips of the thyme, the sun-flower, and several other vegetable substances, when treated with alkali, communicate to it in a certain degree, the property of precipitating iron of a blue colour.

Much reasoning has been exhibited on the etiology of this phenomenon. Messrs. Brown and Geoffroy considered Prussian blue as the phlogiston of iron, developed in the lixivium of blood. The abbé Menon imagined that the colour of iron was blue, and that the phlogisticated alkali precipitated it in its natural colour.

Mr. Macquer refuted the opinion of his predecessors in the year 1752; and proposed a system, in which he considers Prussian blue as iron supersaturated with phlogiston. This skilful chemist proved that the blue is not soluble in any respect in acids; and that the alkalis are capable of dissolving the colouring matter of the Prussian blue, and of becoming saturated with it to such a degree as to be no longer capable of effervescing.

Mr. Sage affirmed that the iron was saturated with the phosphoric acid; and the celebrated Bergmann likewise suspected the existence of some animal acid, as is proved by his notes on the lessons of chemistry of Scheffer. But it was reserved to the celebrated Scheele to convert these suspicions into certainty.



He has proved that the lixivium of blood, exposed for a certain time to the air, loses the property of precipitating iron of a blue colour; and he has shewn that this circumstance depends on the carbonic acid of the atmosphere, which disengages the colouring part. By adding a small quantity of sulphate of iron to this lixivium, it is no longer changed in consequence of its remaining in the carbonic acid. By Boiling this lixivium upon an oxide of iron, it is likewise no longer capable of change in the carbonic acid. The iron has therefore the property of fixing and retaining the colouring principle; but it is necessary that it should not be in the state of oxide.

Prussian blue, treated in the way of distillation with the sulphuric acid, permits a fluid to escape that holds the prussic acid in solution, which may be precipitated upon iron.

The processes of Scheele, to obtain this acid in a state of purity, consist in putting two ounces of pulverised Prussian blue into a glass cucurbit, with one ounce of red precipitate, and six ounces of water. This mixture is to be boiled for some minutes, continually stirring it. It then assumes a yellow colour inclining to green. The fluid being filtered, two ounces of boiling water are to be thrown on the residue. This liquor is a prussiate of mercury, which cannot be decomposed either by alkalis or acids. The solution is then poured into a bottle, in which an ounce of newly-made filings of iron is put: three gros of concentrated sulphuric acid are to be added, and the whole agitated strongly for several minutes. The mixture becomes perfectly black by the reduction of the mercury; the liquor loses its mercurial taste and exhibits that of the colouring lixivium. After suffering it to stand at rest for a time, it is decanted, put into a retort, and distilled by a gentle fire. The colouring principle passes first, because more volatile than water. The operation must be put an end to, as soon as one quarter of the liquor has passed over. As this product contains a small quantity of sulphuric acid, it may be cleared of it by redistilling it from pulverized chalk by a very gentle fire. The prussic acid then comes over in a state of the greatest purity. Scheele recommends that the vessels be well luted, because the acid would otherwise escape on account of its great levity. It is even of advantage to put a small quantity

of water into the receivers, to absorb the acid ; and it would likewise be very proper to surround them with pounded ice.

This acid has a particular smell, which is not disagreeable ; and its taste is sweet.

It does not redden blue paper ; but renders the solutions of soap and of the sulphure of alkali turbid. Mr. Westrumb pretends that the prussic acid is the same as the phosphoric ; for he obtained siderite from Prussian blue, and formed animal earth by mixing the lixivium of blood with a solution of calcareous earth.

The solution of iron in the prussic acid affords Prussian blue. We are indebted to Mr. Berthollet for a very interesting series of experiments upon the prussic acid, and its combinations.

The oxide of iron is capable of existing in two different states in combination with the prussic acid. If the oxide predominates, the combination is yellowish ; but if its proportion be less, the product is Prussian blue. All the acids are capable of dissolving the portion or surplus of oxide which constitutes the difference between the first and second combination.

The prussiate of pot-ash contains oxide of iron. If an acid be poured in, this oxide is dissolved, and is precipitated by double affinity in the form of Prussian blue. The prussiate of pot-ash made by a gentle heat, afterwards evaporated to dryness, then re-dissolved, and filtered, no longer affords the blue upon the addition of acids. It crystallizes in square plates with their edges cut slantways, forming octahedrons, whose two opposite pyramids are truncated. This solution of the prussiate of pot-ash, when mixed with the sulphuric acid, deposits Prussian blue, if it be exposed to the solar light, or to a strong heat. In these processes the prussiate of alkali may be entirely decomposed ; the prussiate of iron, when precipitated by the action of the alkaline prussiate, carries down with it a notable proportion of alkali, of which it may be cleared by washings, which contain the alkaline prussiate. It is the same with regard to precipitations by the prussiates of lime and ammoniac.

The prussiate of mercury crystallizes in tetrahedral prisms, terminating in quadrangular pyramids, whose planes answer to the angles of the prisms. Iron in its metallic state decom-

poses the prussiate of mercury, and deprives it both of its oxigene and its acid. The oxide of mercury likewise decomposes the prussiate of iron and seizes its acid. The prussiate of mercury is but imperfectly decomposed by the sulphuric and muriatic acids. These acids form trifules, or triple salts, with it. The precipitate of the nitrate of barytes by the prussic acid, is not the compound which Bergmann supposed it to be, but is merely a trifule.

The prussic acid readily precipitates alumine from its nitric solution; the alumine nevertheless yields its prussic acid to iron.

The oxigenated muriatic acid, when mixed with the prussic acid, is again converted to the state of common muriatic acid: the prussic acid assumes a more lively smell, becomes more volatile, is deprived of its affinity to alkalis and lime; it precipitates iron of a green colour; and the green becomes blue if the precipitates be exposed to light, or if it be treated with the sulphureous acid.

The prussic acid, impregnated with the oxigenated muriatic acid, and exposed to light, assumes the smell of an aromatic oil, is collected at the bottom of the water in the form of an oil which is not inflammable, and rises in vapour by a gentle heat. By repeating this process it may be totally decomposed; and then this species of oil becomes concrete, and is reduced into crystals.

The acid appears to have undergone a partial combustion in this operation; at least the light and the sulphureous acid do not restore it but by depriving it of oxigene. The oxigenated prussic acid, mixed with lime or a fixed alkali, becomes totally decomposed. Volatile alkali is disengaged; and if the alkali was very caustic, such as the alcohol of pot-ash, it becomes effervescent.

The prussic acid of Scheele is only decomposed in part by this process; whence Mr. Berthollet concludes that it is composed of hydrogen, nitrogen, and carbone.

These experiments do not prove that oxigene exists in this acid. The water affords that which enters into the carbonic acid, produced by the distillation of the prussic acid. Prussian blue takes fire more easily than sulphur, and detonates strongly with the oxigenated muriate of pot-ash. The prussiate of mercury detonates still more strongly

with the nitrate of mercury. The gas of these detonations has not yet been collected. The prussic acid, combined with alkali and the oxide of iron, cannot be separated by any acid without intervention of heat or light; and when it is disengaged, it is no longer capable of separating iron from the weakest acid, unless it be in the way of double affinity. Mr. Berthollet thinks that the elastic state of this acid diminishes this affinity; and that it is necessary, in order that it may easily enter into combination, that it should have lost some of its specific heat. It is this which renders the oxygenated acid so feeble.

Prussian blue afforded me, by distillation, in the ounce, one gros twenty-four grains of ammoniac, thirty-six grains of the carbonate of ammoniac, four gros twelve grains of oxide of iron, or alumine, and one hundred and sixty-four inches of hydrogenous gas burning with a blue flame.

The ammoniac comes over in combination with a small quantity of the colouring principle, which it takes up, and holds in solution: the sulphuric acid renders this visible.

Ammoniac heated upon Prussian blue decomposes it, by seizing the colouring matter.

Lime-water digested upon Prussian blue dissolves the colouring principle by the assistance of a gentle heat; the combination is rapid, and the water acquires a yellow colour. By filtration, the liquor passes of a fine bright yellow, no longer converts syrup of violets to a green, and is no longer precipitated by the carbonic acid. It appears to be completely neutralized, and affords an exceedingly fine blue, when poured into a solution of the sulphate of iron. The prussiate of lime has been proposed, by Messrs. Fourcroy and Scheele, as the most accurate means of ascertaining the presence of iron in any mineral water.

The pure fixed alkalis immediately discolour Prussian blue in the cold. This combination produces heat; and the pure alkalis ought to be preferred to the carbonates of alkali in experiments of this nature.

Magnesia likewise seizes the colouring matter of Prussian blue; but much more weakly than lime-water.

A mixture of equal parts of steel filings and nitrate of pot-ash, thrown into a crucible strongly ignited, detonates



at the end of a certain time, with the disengagement of a considerable quantity of very bright sparks. The residue, when washed and filtered, affords an oxide of iron of a yellowish colour, known by the name of Zwelfer's Saffron of Mars.

Iron decomposes the muriate of ammoniac very well. Two gros of steel filings, and one gros of this salt, afforded Mr. Bucquet, by distillation in the pneumato-chemical apparatus over mercury, fifty-four cubic inches of an aëriform fluid; half of which was alkaline gas, and the other half hydrogenous gas.

This decomposition is founded on the strong action of the muriatic acid on iron.

One pound of the muriate of ammoniac in powder, and one ounce of steel filings, sublimed together, form the martial flowers, or *Ens Martis*. These flowers consist merely of the muriate of ammoniac, coloured, and rendered yellow by an oxide of iron.

The oxide of iron decomposes the muriate of ammoniac much better. This is an effect of double affinity. The ammoniac which rises is sometimes effervescent.

A mixture of good filings of steel and sulphur, moistened with a small quantity of water, becomes heated in the course of several hours. The water is decomposed, the iron rusts, the sulphur is converted into acid, the hydrogenous gas of the water exhales, and the heat is sometimes sufficient to set the mixture on fire. This phenomenon constitutes the volcano of Lemery.

There is the strongest analogy both in the phenomena and effects of the inflammation of this volcano, and the decomposition of pyrites.

Sulphur combines easily with iron by fusion, and then forms a true martial pyrites.

Iron may be alloyed with several metallic substances; but the only alloy which is used in the arts is that which it contracts with tin, to form white iron, or tin plates.

To form the tin plates (commonly known by the name of Tin in England), the softest iron is chosen, which is reduced into very thin plates. Care is taken to polish or clean the surface very well; and this is done in several ways. The pieces are rubbed with sand-stone, and after-

wards kept for three times twenty-four hours in water, acidulated by the fermentation of malt, turning them from time to time. They are afterwards cleaned, dried, and are then ready for tinning. Sal ammoniac is likewise used in some manufactories. For this purpose the plates are disposed in a chamber, in which a certain quantity of sal ammoniac is volatilized. The salt forms a covering over the whole surface of every plate, and possesses the double advantage of clearing it from rust, and affording the coaly principle necessary to prevent the calcination of the metal.

When the iron is well cleared, the plates are plunged vertically into a bath of tin, whose surface is covered with pitch, or tallow. They are turned in the bath; and when taken out they are wiped with saw-dust, or bran.

The uses of iron are so very extensive, that there are few arts which can be practised without it. It is with justice considered as the soul of all the arts. Some of its ores are used in their native state; such as the hæmatites, which is made into burnishers.

The sulphate of iron is the basis of all black colours, inks, &c.

The ochres are used by painters, under the name of Umber; and the brown red has the most extended use. With us (in France) it is applied to give a colour to brick pavements, to paint our doors and windows, to smear our casks, and to secure them from decay and insects in sea voyages.

Cast iron is used to make boilers, chimney-grates, hearths, pots, &c. The instruments of agriculture are made of this metal: steel is used not only as steel; but its hardness renders it proper to cut and work the other metals.

The magnetical property of iron has led to the discovery of the mariner's compass; and this metal, if it were productive of no other advantage to mankind, would on that account be entitled to their greatest attention.

Prussian blue is an agreeable colour, greatly esteemed, and much used.

Iron likewise furnishes the art of medicine with remedies. It is the only metal which is not noxious; and it has such an analogy with our organs, that it appears to constitute one of the elements of the human frame. Its effects in

general consist in strengthening the stomach; and it appears to possess the property of passing in the circulation under the form of æthiops. The valuable experiments of Mr. Menghini, published in the Memoirs of the Institute of Bologna, have proved that the blood of persons who take martial remedies is thicker, and contains more iron. Mr. Lorry observed that the urine of a sick person, to whom he administered iron in a state of extreme division, was manifestly coloured with the nut-gall.

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## CHAPTER XI.

*Concerning Copper.*

**COPPER** is a reddish metal, hard, elastic, sonorous, and affording a disagreeable smell by friction. Its taste is styptic, and nauseous. One cubic-foot of copper weighs five hundred and forty-five pounds. The specific gravity of cast copper not hammered is 7,7880.—Briffon.

The alchemists distinguished this metal by the name of Venus, on account of the facility with which it unites and is alloyed with other metals.

It may be reduced into very thin leaves, and drawn into very fine wire. The tenacity of this metal is such, that a wire of one tenth of an inch in diameter, is capable of supporting a weight of two hundred and ninety-nine pounds four ounces, without breaking.

This metal is capable of affecting a regular form. The abbé Mongez observed it in solid quadrangular pyramids, sometimes inserted into each other.

Copper is found in various forms in the bowels of the earth.

1. Native copper.—This copper exists sometimes in leaves in a gangue of quarts. It is likewise found in compact masses at Japan. There is one of these pieces in the royal cabinet, which weighs ten or twelve pounds.

Native copper is usually disseminated in a brownish martial earth, susceptible of a polish. When this ore is rubbed with a flint, the traces appear of a beautiful copper-colour.

Ores of this kind are found at Kaumfsdorf in Thuringia.—  
Sage, *Analyse Chimique*, t. iii. p. 205.

We have likewise found native copper at Saint Sauveur. It has the form of nodules resembling stalactites. Most of the native coppers appear to be formed by cementation, or by the precipitation of this metal dissolved in an acid, and thrown down by martial salts.

Mr. Sage thinks that this metal may likewise be precipitated from its solutions by phosphorus. To effect, says he, the precipitation of copper by phosphorus, twelve grains of this metal are to be dissolved in half a gros of nitric acid. The solution must be poured into half a pint of distilled water, into which a cylinder of phosphorus, two inches long, weighing forty-eight grains, must be plunged. The surface becomes almost immediately black, and is covered with particles of copper possessing the metallic colour and brilliancy. At the end of several days, octahedral crystals are seen, whose infertions into each other produce elegant dendrites; and at the end of ten days the twelve grains of copper are completely reduced, as is proved by pouring ammoniac into the water. If it do not exhibit a blue colour, it is a proof that the fluid contains no copper.

2. Copper mineralized by sulphur forms the yellow ore of copper.

This ore is of a golden colour, and the ignorant are often deceived by its flattering appearance. It contains a larger quantity of copper in proportion as the sulphur is less in quantity, and gives fewer sparks with the steel. It sometimes crystallizes in beautiful octahedrons. I possess two specimens covered over with trihedral pyramids of near an inch long, and between four and five lines in diameter at the bases.

When the sulphur is so abundant that the proportion of copper will no longer pay for the working, the ore is called Marcasite. The marcasite crystallizes in cubes or in octahedrons, which easily effloresce.

The yellow copper ore is found in various states according to the course of its decomposition. The first impression of hepatic vapours colours the surface in a thousand shades, in which state it is known by the name of Peacocks Tail, Pigeons Neck, &c.



The last degree of alteration of this ore, effected by the simple disengagement of sulphur, forms the hepatic copper ore. The yellow colour is then converted into an obscure brown colour: this ore appears then to contain no other principles but water, copper, and iron, which last is always more or less abundant in these ores.

The yellow copper ore sometimes forms sulphate of copper in its decomposition. This salt is dissolved in water, and forms springs more or less loaded with it, from which the copper may be obtained by cementation. Old iron is thrown into the water; the copper is precipitated, and the iron takes its place. In this way it is obtained in Hungary, and we might use this economical process in several parts of our province. I have stalactites in my collection, sent me from Cevennes, which are coloured blue by a very considerable quantity of copper. In Gevaudan, at half a quarter of a league from St. Leger de Peyre, several springs of water impregnated with copper are found, which run into a valley. The inhabitants of this canton drink a glass of the water occasionally as a purgative.

The skeletons of animals are sometimes found in copper-mines penetrated with that metal. Swedenburg has given an engraving of the figure of the skeleton of a quadruped taken out of a copper-mine, and coloured by that metal. In the royal cabinet there is a human hand, green at the extremity of the fingers, the muscles of which are dried, and greenish. According to the report of Mr. Leyel, consul of mines, there was found at Fahlun in Sweden, in the great copper mine, a human carcase, which had remained there forty years, with the flesh and bones entire, without corruption, and without emitting any smell. The body was clothed, and entirely incrusted with vitriol.—*Acta Literaria Suec. tri. i. anno 1722, p. 250.*

The turquoise stones are merely bones coloured by the oxides of copper. Mr. De Reaumur, in the year 1725, gave an account to the Academy of the turquoises found in Lower Languedoc. The colour of the turquoise frequently becomes converted into green, which depends on the alteration of the metallic oxide. The turquoise of Lower Languedoc emits a fetid smell by the action of fire, and is decomposed by acids. The turquoise of Prussia emits no

smell, and is not attacked by acids. Mr. Sage suspected that the ossaceous part is agatized in these last.

3. Grey copper ore.—The copper is mineralized by arsenic. It has a grey colour, and an appearance nearly vitreous. It usually contains silver; and, when wrought to extract this precious metal, it is called the Grey Silver Ore. It affects a tetrahedral form; and arsenic is the most predominant of its principles.

4. The grey antimonial copper ore.—This differs from the former, because it contains sulphur and antimony; and is much more difficult to be wrought. When exposed to the fire, it becomes as fluid as water; the sulphur is volatilized with the antimony and the arsenic. The residue of the torrefaction is a mixture of the antimony and copper, and sometimes it contains silver likewise.

5. Copper ores, in their decomposition, are reduced to a more or less perfect state of oxidation. The carbonic acid frequently unites to the metal, and becomes the mineralizer. This substance is known by the name of Mountain Blue, Azure of Copper, Mountain Green, Malachite.

A. The azure of copper crystallizes in rhomboidal tetrahedral prisms, rather flattened, terminating in dihedral summits: these crystals are of the most beautiful blue; they are frequently altered by exposure to the air, and become converted into malachite.

Mr. Sage has imitated the azure, both in the form and colour, by dissolving copper, in the cold, in water saturated with carbonate of ammoniac. When the azure of copper is of a less brilliant colour, and in the pulverulent form, it is called Mountain Blue.

B. The malachite, crystallized in octahedrons, has been found in Siberia. This ore is frequently striated, formed into small tufts of a silky appearance, or in very close parallel fibres. The malachite is frequently covered with protuberances. This figure appears to announce that it has been formed in the same manner as the stalactites.

Mountain green differs from the malachite only in its pulverulent form, and the mixtures which alter it. The alterations of the copper ores, and native copper likewise, produce a cupreous oxide, which bears the name of Red Copper Ore. The mine of Predanah, in the county of

Cornwall, has afforded the finest specimens of red copper ore. The metal is nearly in the metallic state, and has the form of octahedral crystals. The granular red copper ore differs from this only in its figure. It sometimes has a brown martial earth for its gangue.

The azure, the malachite, and the red copper require no other process but mere fusion with coal to convert them into metal; the other kinds require to be cleared of their mineralizer by torrefaction, and afterwards to be fused with three parts of black flux.

To assay a sulphureous copper ore, Mr. Exchaquet proposes to make two gros of the crude ore, and one of the nitrate of pot-ash; which, after pulverization, are to be detonated in an ignited crucible. The matter becomes hard after the detonation; upon which the fire is to be increased and kept up, in order that the sulphur may be dissipated. The fire is then to be still more strongly urged, until the ore enters into fusion; and a mixture of half an ounce of tartar, one quarter of an ounce of salt, and a small quantity of charcoal, is to be added in equal portions. An effervescence takes place at each projection of the mixture. The fire is then to be still more strongly raised, and the crucible covered, and kept in this state for half an hour, in order that the copper may flow into a mass. In this way a very malleable button of copper is obtained.

The working of copper ores varies according to their composition. But, as the sulphureous ores are most commonly wrought, we shall confine ourselves to the process which is most suitable to their nature.

The metal is first picked or sorted; afterwards pounded in a mill, and washed, to separate the gangue, and other foreign substances; it is then roasted, to drive off its mineralizer; and afterwards fused in the blast furnace. The result of this first fusion is black copper; which is again fused in the refining furnace, to dissipate all the sulphur which has withstood the preceding operations. When it is very pure, it is poured into a broad vessel, or test; a small quantity of water is thrown on its surface, which, being by that means cooled, separates from the rest, and is taken up. This is the copper in rosettes, which is taken to the hammer to be beat into proper form. The several opera-

tions are different in various places. In some countries, the ore is roasted as often as eight times; in others, one or two are sufficient; and in some places it is not roasted at all. This variety depends—1. On the variations of practice: those who roast but little, employ more time and care in the fusion and refining. 2. On the nature of the ore: when it is rich in iron, the roastings are necessary to dispose this metal to fusion.

The method of roasting is likewise prodigiously varied. Pieces of the mineral are sometimes heaped up on a bed of combustible matter, and in this manner the calcination is performed; but, when this ore abounds with sulphur, it may be extracted by the ingenious process used at St. Bell, and described by Messrs. Jars in their excellent work.

The fusion is commonly performed in the blast furnace; but at Bristol, in England, the ore is roasted in a reverberatory furnace, and fused into black copper.

The refining furnace constructed at St. Bell, by Messrs. Jars, appears to me to be one of the best. They have published an excellent description of it, which may be consulted in their *Mineralogical Travels*. The refining of copper consists in depriving it of the sulphur and iron which it may still retain. The sulphur is dissipated by fire, and bellows properly directed; and the iron is scorified by the assistance of some pounds of lead fused with the copper. The skilful mineralogists whom I have just quoted, make use of a reverberatory furnace, lined with charcoal; and fuse and skim their copper, without using lead.

When the copper contains a sufficient quantity of silver to admit of extraction, the following process is used:—  
1. Seventy-five pounds of copper are fused with two hundred and seventy-five of lead. The alloy is cast into flat pieces, which are called *Loaves of Liquefaction*. 2. These loaves are exposed to a heat sufficient to fuse the lead, which carries the silver with it, and leaves the copper, which, on account of its being more difficult to fuse, retains the original form of the loaves; and is every where penetrated by the interstices through which the fused metal made its escape; these are called *Dried Loaves of Liquefaction*. 3. They are carried into a second furnace, where they are exposed to a stronger heat, to deprive them of the



small quantity of lead which they still retain. 4. The lead is afterwards taken to the cupel, where it is fused, and separated from all the silver it had taken up.

Copper is altered by long exposure to the air. Its surface becomes covered with a greenish coating, which is very hard, and known to the antiquarians under the name of Patin. This is the seal which attests the antiquity of statues and models covered with it.

Copper, exposed to the fire, becomes blue, yellow, and at last violet. It does not flow until it is strongly ignited. When in contact with the coals, it gives a blue greenish tinge to the flame; and, if it be kept a long time in fusion, part of it is volatilized.

When copper is heated in contact with air, it burns at its surface, and becomes changed into a blackish red oxide. This oxide may be separated by striking the plate which has been ignited, or by plunging it in water. When the oxide has been pounded, and more strongly calcined, it assumes a brown red colour, and may be converted into a glass of a brown colour by a more violent heat.

1. The sulphuric acid only acts on copper when concentrated, and very hot. It then dissolves it, and easily affords blue crystals of a rhomboidal form. The sulphate of copper is known in commerce by the name of Blue Vitriol, Cyprian Vitriol, Blue Copper, &c.

Two methods are used to make the sulphate of copper which is met with in commerce. The first consists in calcining the cupreous pyrites, and causing them to effloresce, in order to develop the salt, which is then extracted by lixiviation. The second consists in forming this pyrites artificially, burning it, and lixiviating it, to extract the salt.

This salt possesses a very strong styptic taste. It is easily fusible by heat, which dissipates its water of crystallization, and changes its colour to a blueish white. The sulphuric acid may be extracted by a very strong fire. Lime and magnesia decompose this salt; and the precipitate is of a blueish white colour. If it be dried in the open air, it becomes green. Ammoniac likewise precipitates the copper in a whitish blue: but the precipitate is dissolved nearly at the same instant that it is formed; and the result is a solution of a beautiful blue colour, known by the name of Aqua Caelestis.

This salt contains in the quintal thirty pounds acid, forty-three water, and twenty-seven copper.

2. The nitric acid attacks copper with effervescence, at the same time that it becomes decomposed, and emits abundance of nitrous gas. When it is proposed to obtain this gas by the action of the acid upon the copper, it is necessary to have the precaution of weakening the acid, and to present the copper in pieces of considerable magnitude. If these circumstances be not attended to, the acid attacks the metal with such violence, as suddenly to emit a prodigious quantity of gas; immediately after which an absorption takes place, and the water of the jar passes into the bottle. In this case ammoniac is formed. The diluted nitric acid perfectly dissolves copper: the solution is blue. If it be speedily concentrated, no other result is obtained but a magma without crystals; but if it be left exposed to the air, it affords crystals in long parallelograms. By leaving a solution of this kind to spontaneous evaporation, I have obtained rhomboidal crystals, which, instead of being blue, as they are usually described, are white. They decrepitate upon the coals, emit a red gas by mere heat, and nothing remains but a grey oxide.

3. The muriatic acid does not dissolve copper unless it be boiling and concentrated; the solution is green, and affords prismatic crystals of considerable regularity when the evaporation is slow. This muriate is of an agreeable grass-green colour; its taste is caustic, and very astringent: it fuses by a gentle heat, and congeals into a mass; in which the acid is so adherent, that a very strong fire is required to disengage it. It is very deliquescent. Ammoniac does not dissolve the oxide of this muriate with the same facility as it does that of the other cupreous salts. This observation was made by Mr. De Fourcory; which I think may be explained from the circumstance that the muriatic acid suffers the copper to be precipitated in the metallic form, instead of giving out a portion of its oxigene, which would facilitate the action of the alkali.

4. The acetous acid, when made to act either hot or cold upon copper, only corrodes it, and produces the substance known in commerce under the name of Verdigris. The verdigris which is most used in the arts has been long fabri-

cated at Montpellier exclusively. The prejudice which prevailed, that the cellars of this city alone were proper for this operation, preserved this commerce till lately in its hands. But the progress of information has successively put it in the power of other countries to partake in this manufacture.

The process used at Montpellier consists in fermenting the refuse of grapes with sour wine\*. This refuse is afterwards laid in alternate strata, with plates of copper six inches long and five broad. In this state they are left for a certain time; after which they are taken out, and placed edgewise in a cellar, where they are sprinkled with sour wine: in this situation the verdigris swells up; and is afterwards scraped off, put into sacks of leather, and exported to foreign countries.

Ready-made vinegar is used at Grenoble, and the plates of copper are sprinkled with it.

The verdet or verdigris of Grenoble contains one-sixth less of copper: the vinegar which is obtained is stronger and more abundant. It has not the empyreumatic smell of that of Montpellier. The copper is therefore partly dissolved in the verdet of Grenoble; because it has been first reduced into an oxide by the impression of the vinegar, and afterwards attacked by the subsequent affusion of the same acid. It is therefore an acetate of copper.

The oxides of copper, dissolved in vinegar, form a salt known by the name of Crystallized Verdigris, Crystals of Venus, Acetate of Copper.

To obtain this salt, the vinasse or sour wine is distilled; and this weak vinegar boiled on the verdigris. The solution is then conveyed into a boiler, where it is concentrated until a pellicle appears. Sticks are then plunged in the bath; and at the end of a certain number of days the sticks are again taken out, covered with rhomboidal crystals of a blue colour. These clusters of crystals, weighing each from four to six pounds, are wrapped up in paper, and distributed for sale.

The vinegar may be disengaged by distillation from these crystals; and the residue is a cupreous oxide, which possesses the characters of pyrophorus.

\* Vinasse.

Vinegar, distilled on manganese, dissolves copper; which proves that it has taken up oxygen. The acetic acid, or radical vinegar, differs from ordinary vinegar, in containing a greater quantity of oxygen; and it is this oxygen which renders it proper to dissolve copper in the metallic state. The acetate of copper may likewise be formed by decomposing salt of Saturn, or sugar of lead, by the sulphate of copper. The sulphate of lead falls down; and the solution, when concentrated, affords the cupreous acetate.

5. The pure fixed alkalis, digested in the cold with filings of copper, become of a blue colour; but ammoniac dissolves it much more speedily. I put copper filings into a bottle with very caustic ammoniac, and kept the bottle stopped for two years; the copper was deprived of its colour, and became similar in appearance to a grey clay: whereas a similar vessel, in which I had placed the same mixture, but left open, soon afforded me very small blue crystals; and the whole concluded by affording only a hard stratum of green matter, resembling malachite.

Copper is precipitated from its solutions by iron. For this purpose nothing more is required than to leave the iron in one of the solutions of the other metal, which need not be strong. The phenomenon may be rendered very surprising, by pouring the solution of the sulphate of copper upon the clean surface of a piece of iron; for this surface instantly becomes covered with copper. The copper obtained by this means, is known by the name of Copper Cementation.

This precipitation of one metal by another, has given rise to a belief that the iron was converted into copper: and I could, from my own knowledge, mention the names of individuals who have been imposed on by this phenomenon.

Copper mixes with most of the metals; and forms—

1. With arsenic, the white tombac.
2. With bismuth, an alloy of a reddish white colour, with cubic facets.
3. With antimony, a violet-coloured alloy.
4. It may be combined with zinc by fusion, or by cementation with lapis calaminaris. By the first process, similar, or the Manheim gold, is obtained; the produce of the second is brass.



5. Copper, plunged in a solution of mercury, assumes a white colour, which arises from the mercury which is displaced by the copper.

6. Copper is easily united with tin; and on this depends the art of tinning: for which purpose it is necessary to clean the surface of the metal perfectly; because the oxides do not combine with the metals. This first object is accomplished by rubbing the metal intended to be tinned with the muriate of ammoniac, or by scraping it effectually; or even by passing a weak acid over its whole surface. After this operation the tin is applied by fusing it in the vessel intended to be tinned, then spreading it about with old rags rolled up; and the oxidation of these metals is prevented by means of pitch.

Copper, fused with tin, forms bronze, or bell-metal. This alloy is more brittle, whiter, and more sonorous, in proportion to the quantity of tin that enters into its combination: it is then used to make bells. When it is intended to be applied to the purpose of casting statues, or forming great guns, a larger proportion of copper is used; because in this case solidity is one of the first requisites.

7. Copper and iron contract very little union.

8. Copper, alloyed with silver, renders it more fusible; and these two metals are combined to form folders. Hence it is that verdigris is occasionally observed in pieces of silver, at those parts where joinings have been made by means of folder.

Copper precipitates silver from its solution in the nitric acid. This method is used in the mints to separate the silver from the acid, after the operation of parting.

Copper is very much used in the arts. All the boilers in dye-houses which are intended to contain compositions that do not attack this metal, are made of copper.

It is at present used as a sheathing for the bottoms of ships. All our kitchen utensils are made of it; and, in spite of the danger to which we are daily exposed of being poisoned, and notwithstanding the slow and destructive impression this metal cannot but produce upon us individually, there are few houses from which this metal is yet banished. It is a desirable object that a law might be passed to prohibit its use amongst us; as has been done in

Sweden, at the solicitation of the Baron de Schoffer, to whom the public gratitude has erected a statue of the same metal. It is an allowable infringement of personal liberty, when government take upon them to direct the conduct of individuals in such a manner as to secure their own safety. There is no year passes in which several persons are not poisoned by hams, or other food which is suffered to remain in copper vessels.

Tinning is not a complete remedy against this danger; for it leaves an infinity of points where the copper is uncovered\*.

The sulphate of copper is very much used in dying. The crystals of Venus, and verdigris, are likewise used in painting; they enter into the composition of colours, varnishes, &c.

The various alloys of copper with other metals, renders it highly valuable in the arts. Brass, bronze, and bell-metal, are very extensively useful.

## CHAPTER XII.

### *Concerning Mercury.*

**MERCURY** differs from all other metals, by its property of retaining the fluid state at the ordinary temperature of the atmosphere.

It possesses the metallic opacity and brilliancy; and even acquires malleability when deprived of fluidity by a proper degree of cold. The best ascertained experiment which has been made on this phenomenon, was performed by the Academy of Petersburg, in 1759. The natural cold was increased by a mixture of snow and highly concentrated nitric acid; and the thermometer of De Lisle was caused to fall to 213 degrees, which corresponds with 46 below 0 of Reaumur. At this period the mercury appeared to descend no lower: the bulb of the thermometer being then broken,

\* It may besides be doubted whether the extremely thin white coating, which conceals the internal surface of tinned copper, be not a kind of bell or speculum metal, instead of tin, as it is generally supposed to be. T.

the metal was found to be in a congealed state, and bore to be flattened by the hammer. Mr. Pallas congealed mercury, in 1772, at Krasnejark, by the natural cold: he then found that it resembled soft tin. It has been ascertained in England that the degree of its congelation was the 32d of Reaumur. Mr. Matthew Guthrie, consul at the court of the Empress of Russia, proved that the degree of cold of this congelation was 32 degrees below 0 of Reaumur; and that, when the mercury is purified by antimony, it congeals at 2 degrees lower.—See the *Journal Encyclopédique*, September 1725\*.

Mercury is as indestructible by fire as gold and silver; and its properties in general have caused it to be arranged among the perfect metals.

A cubic foot of this metal weighs 949 pounds; and its specific gravity is 13,5681.—Briffon.

Mercury has been found in the earth in five different states.

1. Virgin Mercury is found in most of the mines of this metal. Heat alone, or mechanical division of the ore, is sufficient to exhibit it in the metallic form.

Native mercury has been found in digging the foundations of some houses at Montpellier; and this metal has been constantly mixed and confounded with a grey or red clay, which forms a bed almost continuous, at a few feet beneath the foundation of this town.

The observations which I have had occasion to make on this subject, have ascertained that the mercury exists in a stratum of decomposed grit-stone, very argillaceous, ferruginous, and ochreous; of a red, brown, or grey colour. In this clay, the globules of mercury, in considerable abundance, were easily distinguishable, lying upon greyish plates. Traces are perceived which resemble dendrites; and its impressions are formed by layers of the oxide of mercury.

Several pounds of mercury have likewise been found in a well at Vienne in Dauphiny; and Mr. Thouvenel has pointed out to us three mines of this metal in the single province of Dauphiny, according to the indications of Bléton.

\* For an account of this subject, see Dr. Blagden's *History of the Congelation of Mercury*, in the seventy-third volume of the *Philosophical Transactions*.

2. Mr. Sage read to the Academy, on the 11th of May 1782, the analysis of an ore of mercury, in the form of a solid oxide, which came from Idria in Friuli. It is of a brown red colour; and its fracture is granulated. It is reducible by mere heat; and affords oxygenated gas. It emits only half the quantity afforded by red precipitate; because this oxide contains metallic mercury. It affords ninety-one pounds of mercury per quintal, and a small quantity of silver.

3. The muriate of mercury, or corneous mercury, has been found native in the mine of Muschel-Lamburg, in the duchy of Deux-Ponts. Mr. Sage obtained eighty-six pounds of mercury per quintal.

Mr. Woulfe has likewise discovered, in 1776, a very ponderous white, green, or yellow crystallized ore of mercury; in which he proved the existence of the sulphuric and muriatic acids.

4. Mercury is sometimes naturally amalgamated with other metals, such as gold, silver, arsenic, copper, &c.

5. Mercury is usually mineralized by sulphur; and the product is cinnabar or æthiops, according to the colour.

Cinnabar is found under different forms. 1. In red crystals, consisting of two triangular pyramids, truncated, and joined base to base, or else separated by a very short intermediate prism. Cinnabar has likewise been found crystallized in transparent plates.

2. Cinnabar is almost always found in masses, more or less compact; the colour varies from deep black to the brightest red. In this last state it is distinguished by the name of Vermillion.

Cinnabar has for its gangue, quartz, clay, calcareous earth, ponderous spar, and even coal. The ore which the Germans called Brandertz, has for its gangue a bituminous matter, which burns perfectly well; and it affords only six pounds of mercury in the quintal.

The principal cinnabar mines which are wrought in Europe, are those of the Palatinate and those of Spain. Mr. Sage informed us, in 1776, of the process used in the Palatinate; and we are indebted to Mr. De Jussieu for a description of the method used in Spain.

In the Palatinate, the pounded and sifted ore is mixed with one third of lime; and the mixture introduced into



iron cucurbits, one inch thick, three feet nine inches long, one foot wide, with an opening of five inches. These vessels are disposed in a gallery. Forty-eight of these retorts being arranged in two parallel lines, a second row is placed above the first. To the neck of each cucurbit an earthen pot is adapted, which is one-third filled with water, and accurately luted on. The gallery is heated at the two extremities; several apertures formed in the dome serve the purpose of chimneys; and the distillation is effected by a fire kept up for ten or twelve hours.

This process was followed at Almaden till the year 1647, when the following was adopted, as being more simple and economical. The furnace is twelve feet high, and four feet and a half diameter within. At the distance of five feet and a half from the ground, is an arch upon which the ore is disposed, and a fire is kindled in the ash-hole. The sublimed mercury escapes through twelve apertures formed in the upper part of the laboratory. To these apertures, rows of aludels, inserted one in the other, are adjusted, and disposed parallel upon a terrace, which terminates in a small building separated into as many chambers as there are files of aludels. Each chamber has a cavity in the middle, to receive the small quantity of mercury which may arrive to that distance.

Every furnace contains two hundred quintals of cinabar, and the fire is kept up for three days. The sulphur which burns is disengaged in the form of sulphureous acid, and escapes through small chimneys made in each chamber. Every repetition of the process affords from twenty-five to sixty quintals of mercury.

The mine of Almaden has been wrought from time immemorial. Its veins are from three to fourteen feet in breadth; and their breadth is even larger where they join.

Hitherto no method has been discovered to fix mercury but that of extreme cold. This metallic substance, naturally fluid, is capable of rising even by a very moderate fire; as is proved by an experiment of Mr. Achar'd, who having left a dish containing twenty pounds of mercury over a furnace which was daily heated, experienced a salivation at the end of several days; as did likewise two other persons who had not quitted the chamber. He estimates

this heat at about eighteen degrees of Reaumur.—*Journal de Physique*, October 1782.

It is dangerous to oppose the evaporation or dilatation of this metal which is produced by heat.

In the year 1732 an alchemist presented himself to Mr. Geoffroy, pretending he had discovered the means of fixing mercury. He inclosed the metal in an iron box, and this box in five others, which were placed in a furnace; the explosion was so strong, that it burst through the boards of the floor. Mr. Hellot has related a similar fact to the Academy.

Mercury boils in the same manner as other liquids when it is heated; and for this purpose it does not even require a very considerable heat; the ebullition consists merely in its transition to the vaporous state: for it may be distilled like all other fluids, and by that means cleared of its impurities. Boerhaave had the patience to distil the same mercury five hundred times successively; and the metal suffered no other change, than that it afforded a grey powder, which required only trituration to convert it again into running mercury.

Mercury is not easily changed in the air; but if the action of the air be assisted by heat, the mercury gradually loses its fluidity; and at the end of several months forms a red oxide, which alchemists have distinguished by the name of *Precipitate per se*. The apparatus made use of for this operation is a very large and very flat bottle, closed with a stopper, in which there is a capillary perforation. The mercury within the bottle by this means possesses the contact of air; and by disposing the apparatus upon a sand bath, and keeping up the state of ebullition in the fluid, the oxide may be obtained in the course of several months.

This oxide gives out its oxigene by simple heat, without any intermedium; and the mercury resumes its metallic form: one ounce affords about a pint. A quintal of mercury takes up about eight pounds of oxigene. The red oxide of mercury, exposed to heat, sublimes in close vessels, and may be converted into a very beautiful glass. I have observed this on all occasions when I have made the red oxide by means of the nitric acid, according to the process which I shall immediately describe.

It is certain that mercury upon which water is boiled, communicates a vermifuge property to that liquid, though the most accurate experiments of Lemery have shewn that the metal does not perceptibly lose weight; which proves that the principle taken up by the water is very fugacious, and so light that it does not constitute any sensible part of the weight. Water which has remained for a certain time over mercury contracts a very evident metallic taste.

1. The sulphuric acid does not act upon mercury unless assisted by heat. In this case, sulphureous gas is disengaged; and a white powder falls down, the quantity of which becomes greater in proportion as the acid is decomposed. This oxide weighs one third more than the mercury made use of. It is caustic: if hot water be poured on it, it becomes yellow; and if it be urged by a violent heat, it affords oxygenous gas, and the mercury resumes its natural form. This yellow oxide, obtained by means of the sulphuric acid, is known by the name of Turbith Mineral. It has long been considered as a sulphate of mercury. Mr. Baumé has proved that it does not contain a particle of acid; and it appears that the water which develops its yellow colour, seizes the small quantity of undecomposed acid which was mixed with the oxide. If the water which has been poured on it be evaporated, a salt is obtained in small, soft, and deliquescent needles, which may be deprived of their acid by the simple affusion of water. This fluid precipitates the mercury from them in the form of turbith.

2. The nitric acid of commerce, at the strength of thirty-five degrees, dissolves mercury with violence, even without the assistance of heat. This solution is accompanied with the disengagement of a considerable quantity of nitrous gas; because it is necessary that the acid should reduce the metal to the state of oxide before it can act upon it. One part of the acid is consequently employed in disposing the metal for solution, and the other dissolves it in proportion as it is oxidized. This is what happens when the sulphuric acid is digested upon a metal; one portion is decomposed, and reduces the metal into an oxide, while the other dissolves it.

The manner of effecting the solution of mercury in the nitric acid, has an influence on the properties of the mer-



curial nitrate. Bergmann has observed that the solution which is made slowly and quietly, without disengagement of nitrous gas, affords no precipitate on the addition of water; whereas that which is made by the assistance of heat, and with loss of nitrous gas, affords a precipitate. It appears that the nitric acid, assisted by heat, is capable of becoming loaded with an excess of mercurial oxide, which it lets fall when diluted with water.

The method of performing the solution, and the process made use of to crystallize it, has an equal influence upon the form of the crystals. 1. The solution made in the cold, and left to spontaneous evaporation, affords crystals which appeared to Mr. De Lisle to be octahedral pyramids, truncated near their base, and having the four angles resulting from the junction of the bases of their pyramids likewise truncated. 2. If the same solution be evaporated, long and acute blades are obtained, laying one upon the other, and striated obliquely across. 3. The solution of mercury effected by heat, affords flat and acute needles, striated lengthways.

The nitrate of mercury is corrosive; it detonates upon coals when it is very dry, and emits a whitish flame of considerable brilliancy.

The mercurial nitrate, heated in a crucible, is fused, and emits a considerable quantity of nitrous gas together with its water of crystallization. The remaining oxide becomes yellow; and at length assumes a lively red colour, and forms the substance called Red Precipitate. In order to make a very fine red precipitate, the mercurial solution must be put into a retort, and distilled until no more vapours come over. An additional quantity of nitric acid must then be poured on the remainder, and likewise distilled off. After three or four repeated distillations, a very beautiful precipitate is obtained in small crystals of a very superb red colour.

The solution of mercurial nitrate forms mercurial water. It is of use to ascertain the presence of sulphuric and muriatic salts in mineral waters.

The acids, the alkalis, the earths, and some of the metals, likewise precipitate mercury from its solution in the nitric acid. These precipitates always consist of the oxides of



mercury in a greater or less degree of perfection, according to which circumstances their colour is subject to variation. On this head, Lemery, Baumé, &c. may be consulted.

Mr. Bayen has discovered that some of these precipitates possess the property of fulminating, when mixed with a small quantity of sublimed sulphur. This chemist has pointed out three—1. The precipitate of mercury from its solution in the nitric acid by the assistance of the carbonate of ammoniac. 2. The precipitate of the same fluid by lime-water. 3. The precipitate of the solution of corrosive sublimate by lime-water. Half a gros is to be triturated with six grains of sublimed sulphur. After the detonation, a violet coloured powder remains, which affords a fine cinnabar by sublimation.

3. The muriatic acid does not sensibly act upon mercury: but if it be digested for a long time upon the metal, it oxides it, and at length dissolves the oxide, as may be concluded from the experiments of Homberg, inserted in the volume of the Academy of Sciences for the year 1700.

The muriatic acid completely dissolves the mercurial oxides. When these oxides are nearly in the metallic state, or charged with a small quantity of oxigene, the muriate of mercury is formed. When, on the contrary, the oxide of mercury is saturated with oxigene, the oxigenated muriate of mercury, or corrosive sublimate of mercury, is formed.

Corrosive sublimate may be formed according to two methods; in the dry way, or in the humid way.

To make this salt in the dry way, the operator may proceed in various manners.

1. Equal parts of dried nitrate of mercury, decrepitated muriate of soda, and sulphate of iron calcined to whiteness, are mixed together. This mixture being exposed to sublimation, the product which arises is corrosive sublimate.

2. Running mercury is used in Holland instead of the nitrate of mercury; and the same results may be obtained by using any oxide of mercury whatever.

3. Equal parts of the sulphure of mercury, and the decrepitated muriate of soda, afford the same salt by sublimation. This process of Kunckel has been revived by Boulduc.

4. Mr. Monet assures us that he obtained corrosive sublimate by treating the dry muriate of soda, and a mercurial oxide, in the way of distillation in a retort.

If mercury be dissolved in the oxygenated muriatic acid, the solution, when concentrated, affords very fine corrosive sublimate. It may likewise be obtained by precipitating the mercury from mercurial water by the same acid, and evaporating the solution.

I have obtained very fine sublimate by presenting a mercurial oxide, sufficiently loaded with oxigene, to the ordinary muriatic acid. One pound of muriatic acid, at the strength of twenty-five degrees, poured upon one pound of red oxide by the nitric acid, discolours it, in a short time dissolves it with a violent heat; and this solution, diluted with water, and properly evaporated, affords from twelve to fourteen ounces of crystals of corrosive sublimate.

The corrosive muriate of mercury has a styptic taste, followed by an exceedingly disagreeable metallic taste. When placed on hot coals, it is dissipated in fumes; when slowly heated in subliming vessels, it rises in prismatic crystals, so much flattened, that their faces are scarcely distinguishable. The assemblage of these has induced authors to compare them to sword blades lying across each other.

This salt is soluble in nineteen parts of water; and when the solution is concentrated, it affords crystals similar to those obtained by sublimation.

Barytes, magnesia, and lime decompose this salt. Half a gros of corrosive sublimate in powder, thrown into a pint of lime-water, forms a yellow precipitate. This fluid is known by the name of Phagedenic Water.

Fixed alkali precipitates the mercury in an orange-coloured oxide; and volatile alkali in the form of a white powder, which becomes brown in a short time.

The same muriatic acid, combined with a less perfect oxide of mercury, forms the mild muriate of mercury, or mercurius dulcis. This combination may likewise be made by two methods; by the dry, or the humid way.

1. In the dry way, four parts of corrosive muriate of mercury are triturated in a mortar with three of running mercury. When the mercury has disappeared, the mixture is put into phials, and sublimed three successive times, in order that the combination may be more accurate. This sublimate differs from corrosive sublimate by its insolubility in water, its insipidity, and the form of its crystals, which

are tetrahedral pyramids, terminated by four-sided pyramids. To obtain this regular form, it is necessary that the sublimation should be made at a moderate heat; for, if the heat be sufficient to liquefy the salt, the result is merely a crust, with no appearance of crystals. As the trituration of corrosive sublimate is dangerous, on account of the powder which rises, Mr. Baumé pours a small quantity of water upon the mixture. This liquid accelerates the trituration, and prevents the rising of the destructive powder.

Mr. Bailleau has proposed the incorporating of corrosive sublimate with water, and triturating it with running mercury. The combination is completed by digesting the mixture on a sand bath by a gentle heat. The matter becomes white, and requires only a single sublimation. Whenever it is suspected that mercurius dulcis still retains a portion of corrosive sublimate, nothing more is necessary to be done than to triturate it, and pour boiling water upon it; for by this means the whole of the soluble salt which may have remained, is carried off.

Mr. Baumé has proved that there is no intermediate state between mercurius dulcis and corrosive sublimate. If less mercury be added to the sublimate, a proportional quantity of mercurius dulcis only sublimes, and the rest rises in the form of corrosive sublimate; if a greater quantity of mercury be added than is necessary to convert the whole into mercurius dulcis the excess remains in the form of running mercury.

The same chemist has likewise proved, that a portion of the mercury is always lost at each sublimation; and that a small quantity of corrosive sublimate is formed, which arises from the alteration of the mercury. Hence it follows that the mercurial panacea, which is made by subliming mercurius dulcis eight or nine times, is a more suspicious remedy than the mercurious dulcis itself.

2. Mercurius dulcis may likewise be made by decomposing mercurial water by a solution of the muriate of soda. The white precipitate which is obtained may be sublimed, and forms an excellent mercurius dulcis. I communicated this process to the Society of Sciences at Montpellier two years before Mr. Scheele made it known.

The corrosive muriate of mercury differs therefore from the mild muriate by the state of its acid.

The mercurial oxides are equally soluble in the other acids.

3. A solution of borax, mixed with mercurial water, forms a very abundant yellow precipitate, which is nothing else but the combination of the acid of borax and mercury. A small quantity of this salt remains in solution, which may be obtained in brilliant crystals by evaporation.

4. The acetous acid likewise dissolves the oxide of mercury, and affords white foliated crystals.

Mercury precipitated from a solution of the acetate of mercury, combines with the acidulous tartrite of pot-ash, and forms vegeto-mercurial water of Preßavin.

The acetate of mercury is the basis of Keyser's pills.

5. Mercury, artificially mixed with sulphur, forms the red or black sulphures, known, on account of their colour, by the names of *Æthiops* or *Cinnabar*.

To form the *æthiops*, or black oxide of mercury, three methods may be followed.

1. Four ounces of mercury may be triturated with twelve ounces of sublimed sulphur in a glass mortar. The result is a black powder, called *Æthiops Mineral*.

2. Four ounces of sulphur may be fused in a crucible, and one ounce of mercury extinguished in it. The mixture readily takes fire, but the inflammation is to be prevented; and the blackish residue, being pounded, affords a greenish powder, which is a true *æthiops*.

3. The *æthiops* may be made by pouring the sulphure of pot-ash upon mercurial water.

These *æthiops* afford by sublimations *cinnabar*, or the red sulphurated oxide. But in order to make it with a greater degree of accuracy, four ounces of sublimed sulphur are fused in an unglazed earthen pot, and one pound of mercury mixed with it by stirring or agitation. When these substances have combined to a certain degree, the mixture spontaneously takes fire, and is suffered to burn about a minute. The flame is then smothered, and the residue pulverized, which forms a violet powder, usually weighing about seventeen ounces five gros. This powder, being sublimed, affords a sublimate of a livid red colour; which, when pounded, exhibits a fine red colour, known by the name of *Vermilion*.

Three parts of *cinnabar*, mixed with two ounces of iron filings, afford very pure mercury by distillation, which is



called mercury revived from cinnabar. Lime, the alkalis, and most of the metals, may be substituted instead of the iron.

Mercury amalgamates with most other metals. On this property is founded the art of water-gilding, or gilding upon metals, the tinning of glasses, the working of gold and silver mines, &c.

Mercury is likewise used in the construction of meteorological instruments, in which it possesses the advantage over other fluids—1. That it does not easily freeze. 2. It is more easily and gradually dilatable, according to the fine experiments of Messrs. Bouquet and Lavoisier. 3. It is very nearly of the same quality in different specimens.

Mercury may be used in substance as a remedy against the *volvulus*, and it has never been observed to produce bad effects. It is mixed with fat, to form unguents very much used in venereal cases. These are prepared with one-third or half their weight of mercury, according to the exigence of the case.

The mercurial water is used as an escharotic.

The red oxides answer the same purpose.

The mild mercurial muriate is used as a purgative. It enters into the composition of pills which are used in venereal cases, with the intention of carrying off the morbid matter by the skin.

The corrosive muriate of mercury is of very extensive use, more especially against venereal disorders. This remedy requires skill and prudence; but I have received it as the common opinion of all physicians of reputation, that it is the most powerful and certain remedy possessed by the art of medicine. In a large dose it irritates the system, affects the stomach, occasions spasms in the lower belly, and leaves impressions which are difficult to be eradicated.

Cinnabar is used in fumigations, to destroy certain insects which attach themselves to the skin. It is likewise used as a pigment.

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## CHAPTER XIII.

### *Concerning Silver.*

SILVER is a metal of a white colour, possessing neither smell nor taste, nearly unalterable by fire, very ductile and tenacious. A cubic foot of this metal cast weighs

seven hundred and twelve pounds; the specific gravity of cast silver is 10,1752. See Briffon.—It is found in the earth in five different states, which we shall proceed to consider.

1. *Virgin or native silver.*—Native silver is found in various forms. 1. In ramifications composed of octahedrons inserted one in the other. This variety is known by most mineralogists under the name of *Virgin Silver in Vegetation*. Four processes, indicated by Mr. Sage, are known for the crystallization of silver: amalgamation, reduction by phosphorus, reduction by copper, and fusion:

A detail of these four processes may be seen in his *Analyse Chimique*, book iii. p. 238, et seq.

Native silver is likewise found in small capillary, flexible, and intertwined threads. The decomposition of the red or vitreous silver gives rise to this species; it may even be produced by a slow calcination of one of these ores.

Silver is likewise found in irregular forms; either in small plates dispersed in the gangues, or in masses. Albinus reports, in the *Chronicle of the Mines of Misnia*, that in the year 1478 a lump of native silver was found at Schneeberg, weighing four hundred quintals. Duke Albert of Saxony descended into the mine to see this surprising mass of silver, and had dinner served up upon it.

2. *The vitreous silver ore, or silver mineralized by sulphur.*—This ore is of a grey colour, and may be cut like lead. It crystallizes in octahedrons, or in truncated cubes, and is most frequently found of an indeterminate figure. The sulphur may be extracted by heat. It affords about sixteen pounds in the quintal.

When the sulphur is contained in a greater proportion in this ore, it becomes black, porous, and friable.

3. *Red silver ore: silver mineralized by sulphur and arsenic.*—This species crystallizes in hexahedral pyramids, terminating in an obtuse trihedral pyramid, with rhombic faces. It is frequently found in irregular masses of no determinate figure. It possesses the colour and transparency of the ruby.

Mr. Sage has obtained from this ore, by distillation, water, carbonic acid, and the sulphurated yellow and red oxides of arsenic. If this ore be calcined in a test, and the mineralizer be suffered to exhale, the residue is found to be in the metallic state, exhibiting contorted threads of

silver at its surface. Part of the silver passes to the state of grey oxide in this operation.

4. White antimonial silver ore: silver and antimony mineralized by sulphur.—This ore is as white as silver; it is brittle, and of a granulated fracture. Sometimes it is found in hexahedral prisms, truncated and flat at each end: this kind is found in the principality of Furstenburg. When exposed to heat, it becomes as fluid as water, emits antimony and sulphur, and leaves the silver behind, together with an oxide of antimony. This semi-metal is cleared off by fusion, assisted by proper fluxes, and cupellation.

5. The corneous ore of silver, or muriate of silver.—This species is of a dirty yellow grey: it is soft, and may be easily broken or cut. A gentle heat causes it to flow; it sublimes without decomposition, is most frequently found of no regular form, but sometimes crystallized in cubes. The muriatic acid is its mineralizer. Mr. Woulfe has shewn that it likewise contains a small quantity of sulphuric acid.

6. Silver is also very frequently alloyed with various metals, such as lead, copper, bismuth, cobalt; and these ores are sometimes wrought on account of the quantity of silver they contain.

The manner of working a silver ore varies according to its nature; but all the processes used in various countries may be reduced to the following:

1. In Peru and Mexico the mineral is pounded, roasted, washed, and afterwards triturated with mercury in copper boilers filled with water kept at the boiling heat. The whole is agitated by means of a kind of mill. The amalgam is afterwards expressed in a skin; then heated, to drive off the remaining mercury; after which process the silver remains alone.

This method is defective—1. Because the fire volatilizes a portion of the muriate of silver which abounds in these ores. 2. The washings carry with them a portion of the oxide of silver. 3. The mercury does not amalgamate either with the muriates of silver, or the sulphates of that metal.

2. When silver ores, mineralized by sulphur or arsenic, are to be wrought, they are roasted, pounded, washed, and fused with lead. This metal seizes all the silver, from which it is again separated by cupellation.

3. When the silver ore is poor, it is fused with cupreous pyrites, and the mixture treated in the way of liquation.— See the article Lead.

To determine the degree of purity of the silver, a given weight of silver is supposed to be composed of twelve parts, called pennyweights; each pennyweight is divided into twenty-four grains. Silver, clear of all mixture, is said to be twelve pennyweights fine.

In order to assay silver, and to ascertain its degree of fineness, the regulation of the Court of Monies of France prescribes, that thirty-six grains of silver be taken, and wrapped in a plate of lead containing no fine metal, and then exposed to cupellation. From the loss which the button of silver that remains on the cupel has suffered, a judgment is made of the quantity of alloy. If the loss be one-twelfth of the whole, the silver is said to be eleven pennyweights fine. The details relating to this operation may be seen in *L'Art d'essayer l'Or et l'Argent, par M. Sage*.

Silver may be rendered hard by mixing it with copper; and for this reason it is alloyed with that metal for silversmiths work, as well as for the coinage. The law permits one-twelfth of alloy in silver money\*; and it is this portion of copper which renders the solution of silver coin in the nitric acid blue.

Silver is not changed by the contact of air. A considerable heat is required to fuse it; but it may be volatilized by strong fire without alteration, as is proved by the capital experiments of the Academicians of Paris, made in the focus of the lens of Mr. Trudaine. This metal emits a thick fume, which whitens plates of gold exposed immediately over it.

Junker converted silver into glass, by treating it in a way of reverberation, after the manner of Isaacus Hollandus, in a very strong fire.

Macquer, by exposing silver twenty times successively to the porcelain furnace of Seves, obtained glass of an olive green colour. It was likewise observed that this metal, when exposed to the focus of a burning mirror, presented a white pulverulent matter on its surface, and a greenish vitreous covering on the support upon which it was placed.

\* The British coinage is 11 ounces 2 pennyweights fine. T.



Though these experiments clearly prove that silver is capable of combining with oxygen, the difficulty which is found in effecting this combination, and the facility with which this air is disengaged from the oxides of silver, prove that there is but little affinity between these two substances.

If silver in a state of extreme division be presented to the concentrated and boiling sulphuric acid, sulphureous gas is disengaged: the silver is reduced into a white matter, which is a true oxide of silver; and contains a small quantity of sulphate, which may be obtained in small needles, or in plates formed by the union of these needles lengthways, as Mr. De Fourcroy has observed. This salt flows by heat, and is very fixed. If silver be precipitated by metals or alkalis, these precipitates are reducible without addition.

The nitric acid dissolves silver with rapidity: much nitrous gas is disengaged. The solution is at first blue: but this colour disappears when the silver is pure; and degenerates into a green colour, if it be alloyed with copper. The nitric acid is capable of dissolving more than half its weight of silver. The solution then lets fall crystals in hexagonal, triangular, or square plates, which are called Nitrate of Silver, Lunar Crystals, Lunar Nitre, &c.

The solution of these crystals, generally known by the name of Solution of Silver, is very caustic. It colours the skin black, burns the epidermis, and so completely destroys its organization, that the spot disappears only by the renewing of the skin.

The nitrate of silver melts on burning coals; but if it be exposed to a gentle heat, in earthen or metallic vessels, it liquefies, and may then be cast in moulds. This fused nitrate of silver forms the lapis infernalis. Care must be taken to pour it out as soon as it is fused; because otherwise the acid would be disengaged, the silver would be revived, and the lapis infernalis, or lunar caustic, would lose its virtue.

Lapis infernalis, made with pure silver, and prepared as above described, is whitish; whereas it is blackish when suffered to remain in fusion for any time.

Lapis infernalis is very frequently mixed with nitrate of copper. This fraud is reprehensible, because it is an alloy which renders wounds of a bad character.

The lapis infernalis is used as an escharotic, and to corrode fungous excrescences.

Silver may be precipitated from its solution by lime-water, alkalis, and several metals. These last exhibit very important phenomena.

1. A plate of copper, immersed in a solution of silver diluted in water, precipitates the metal. It adheres at the moment of precipitation to the surface of the copper, where it forms a kind of moss. In proportion as the silver is precipitated, the water assumes a blue tinge; which proves that the copper is dissolved in the nitric acid, in the room of the silver. When the whole of the silver is disengaged, the water is to be decanted, the silver dried, and fused in crucibles, to be cast into ingots. This silver almost always retains a small quantity of copper; of which it may be deprived by cupellation with lead, which renders the silver pure: this process is used in the mints, where the parting operation of gold from silver is performed. The first step consists in separating the silver by means of nitric acid; and this is afterwards precipitated by the addition of copper.

2. The silver is likewise precipitated by mercury. In this operation it amalgamates with a small quantity of the mercury, and forms tetrahedral crystals terminated by a tetrahedral pyramid, which crystals are articulated into each other. This arrangement gives them the form of a vegetation; and has caused the precipitate to be known by the name of the Tree of Diana, *Arbor Dianæ*. Lemery, Homberg, and other chemists, have successively published processes to produce this phenomenon; but that which has succeeded best in my hands, is described by Mr. Baumé. Six gros of the solution of silver, and four of that of mercury, both well saturated, are taken, and diluted with five ounces of distilled water. These are to be put into a conical vessel; and an amalgam of seven parts of mercury, and one of silver, is to be poured in. A multitude of small crystals instantly appear to disengage themselves from the surface of the amalgam, upon which new ones articulate themselves; and a vegetation is produced, which perceptibly rises under the eye of the spectator. To render this phenomenon more striking, I decant the exhausted water, and substitute fresh: by this

means I can fill any vessel whatever with these vegetations. The mercury amalgamated with the silver, in this operation, may be separated by means of fire.

The muriatic acid does not dissolve silver, but it speedily dissolves its oxides. The oxygenated muriatic acid dissolves silver.

To produce a certain and speedy combination of the muriatic acid with silver, this acid is to be poured into a solution of the nitrate of silver. A precipitate immediately falls down, which is known by the name of Luna Cornea. This muriate of silver is very fusible; and runs into a grey and transparent substance, considerably resembling horn. If a stronger degree of heat be applied, it is decomposed, part is volatilized, and the other part reduced into silver.

The muriate of silver, exposed to the light of the sun, becomes brown in a short time. Oxygenous gas is disengaged; which may be collected by placing it under water, according to the process of Mr. Berthollet. Most of the solutions of the metals have the same property. Lunar nitre likewise becomes coloured, and emits its oxygen and nitrous gas.

One pound of boiling water does not dissolve more than three or four grains of muriate of silver, according to the observation of Mr. Monet. The alkalis are capable of decomposing the muriate of silver, and separating the metal. The silver may be disengaged from its muriate by fusion with three parts of black flux.

Mr. Berthollet has taught us the following process, to form the most dreadful and the most astonishing fulminating powder we have yet been acquainted with. Take fine silver of cupellation; dissolve it in nitric acid; precipitate this solution by lime-water; decant the water, and expose the oxide for three days to the air. Mr. Berthollet is of opinion that the presence of light has some influence in the success of this experiment.

Mix this dried oxide in ammoniac, or volatile alkali, and it will assume the form of a black powder: decant the fluid, and leave the powder to dry in the open air. This is the fulminating silver.

Gunpowder, and even fulminating gold itself, cannot be compared with this new product. The contact of fire is necessary to cause gunpowder to detonate; and a determi-



nate degree of heat is required to cause fulminating gold to fulminate ; but the contact of a cold body is sufficient to produce the detonation of fulminating silver. In a word, this product, once obtained, can no longer be touched : no attempts must be made to inclose it in a bottle, but it must be left in the capsule wherein the evaporation was performed.

It is useless to observe, that the fulmination ought not to be attempted but with small quantities ; the weight of a grain, for example : for a larger mass would give rise to a dangerous detonation. The necessity of making this preparation with the face covered with a mask with glass-eyes, may be easily conceived. It is prudent to dry the fulminating silver in small metallic capsules.

The following experiment will complete the notion which ought to be formed of the fulminating property of this preparation.

Take the ammoniac which was used in the conversion of the oxide of silver into the black precipitate which forms fulminating silver : put this ammoniac into a small matraass of thin glass, and let it be subjected to the degree of ebullition necessary to complete the combination. Take the matraass from the fire ; and a rough covering of crystals will be formed on its internal surface which is beneath the fluid. If one of these crystals beneath the cold fluid be touched, an explosion takes place which breaks the matraass.

The process for obtaining fulminating silver being described, its effects known, and the cautions necessary for repeating the experiment being well ascertained, we shall speak a word concerning the theory of the phenomenon : it is the same as that of fulminating gold, laid down by Mr. Berthollet. — See the Memoirs of the Royal Academy of Sciences, for the year 1785.

In this operation, the oxygen, which adheres very slightly to the silver, combines with the hydrogen of the ammoniac. From the combination of the oxygen and the hydrogen, water in the state of vapour is produced. This water, instantly vaporized, and possessing all the elasticity and expansive force of that state, is the principal cause of the phenomenon ; in which the nitrogen, which is disengaged from the ammoniac, with its whole expansibility, likewise bears a principal part.



After the fulmination, the silver is found reduced or revived; that is to say, it has resumed its metallic state. It again becomes the same white, brilliant, and pure metal which it was when taken out of the cupel.

The principal use of silver is in coinage, as the representative sign of the value of other commodities.

Its metallic brilliancy has caused it to be adopted as an ornament; its hardness, and unchangeableness in the air, render it very valuable.

It is alloyed with copper, to form solder; whence it happens that silver utensils are subject to rust and verdigris, at the places where they are soldered.

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## CHAPTER XIV.

### *Concerning Gold.*

**GOLD** is the most perfect, the most ductile, the most tenacious, and the most unchangeable, of all the known metals. A cubic foot of pure gold, cast and not hammered, weighs 1348 pounds; and its specific gravity is 19,2581.—See Briffon.

Gold has neither smell nor taste; its colour is yellow, and this varies according to the purity of the metal.

1. As Gold is subject to very little alteration, it is almost always found in the native state; and under this form it exhibits the following varieties:—1. It is found in octahedrons in the Gold mines of Boitza in Transylvania. These octahedrons are sometimes truncated in such a manner as to have the appearance of hexagonal plates. This native gold is alloyed with a small quantity of silver; which, according to Mr. Sage, gives it a pale yellow colour. It has likewise been found crystallized in tetrahedral prisms, terminated by four-sided pyramids. The amalgam made with certain precautions is likewise capable of causing gold to assume a form nearly similar, according to Mr. Sage; and gold reduced by phosphorus sometimes exhibits octahedral crystals.

Gold likewise crystallizes by fusion. Messrs. Tillet and Mongez obtained it in short quadrangular pyramids.

2. Native gold sometimes exhibits fibres or filaments of various lengths; it is likewise found in plates disseminated on a gangue. The gold ore of Lagardet, a few leagues distant from Alemont in Dauphiny, is of this kind. 3. Gold is likewise found sometimes in small plates or spangles, dispersed in sand or earths: under this form it is found in the auriferous rivers, such as the Ariege, the Ceze, the Gardon, the Rhone. These small plates are sometimes one line in diameter, but most commonly too small to be seen by the naked eye. 4. Gold is sometimes found in irregular masses; in which instance it is known by the name of Gold Dust. Very large pieces of this kind are found in Mexico and Peru.

3. Gold is sometimes mineralized by sulphur, by the means of fire. The auriferous pyrites are frequently found in Peru, Siberia, Sweden, Hungary, &c. To ascertain whether a pyrites contains gold or not, it must be pounded, and nitric acid poured upon it until it takes nothing more up. This solution must then be diluted with much water. The lightest insoluble parts may be carried off by washings; and the residue, upon examination, will shew whether it contains gold or not.

When the martial pyrites is decomposed, the gold is always disengaged; and it is probable that the small plates of gold in the auriferous rivers, are afforded by a decomposition of this kind.

Gold is sometimes mineralized by sulphur, with the assistance of zinc, as in the gold mine of Nagyag. This ore likewise contains lead, antimony, copper, silver, and gold.

4. Mr. Sage has given a description and analysis of an arsenical ore of gold.

5. Gold likewise exists naturally in vegetables. Becher obtained it. Henckel affirmed that they contain it; and Mr. Sage has resumed this enquiry, and found it according to the following table, which expresses the quantities of gold obtained from the quintal of the several earths.

	Ounces.	Gros.	Grains.
Rotted manure (terreau)	0	1	56
Earth of uncultivated ground	0	2	36
(terre de Bruyere)			
Garden mould	0	5	0
Mould of a kitchen garden	2	3	40
manured with dung yearly			
for sixty years			

These results were at first contested; but at present it appears to be generally agreed that gold is obtained, but in a less quantity. Mr. Berthollet obtained forty grains and eight twenty-fifths of gold in the quintal of ashes. Messrs. Rouelle, Darcet, and Deyeux likewise obtained it.

It is therefore a physical fact, that gold exists in vegetables.

The method of working the ores of gold is nearly the same as that used with silver ores. When the gold is in a native state, nothing more is required than to divide the ore by the pounding mill, and afterwards to wash and amalgamate it. If the ore be mineralized, it is torrefied, pounded, washed, fused with lead, and afterwards cupelled. Eliquation is likewise used for poor ores.

Those persons who explore the gold in small plates disseminated in the sand of certain rivers, are known in France by the name of Orpailleurs, or Pailloteurs. The pailloteurs of the river Uze, after having ascertained that the earth is sufficiently rich to be wrought, place a table of several feet in length, and about a foot and a half in width, on the banks of the river with ledges round three of its sides. Pieces of stuff with a long nap are nailed on to this board; and the sand is thrown upon it, and washed, to carry away the lighter particles. When the stuff is sufficiently charged with the small particles of gold, it is shaken into a vessel, agitated with water to carry off the lightest sand, and afterwards amalgamated with mercury\*. Mr. Ell has given us an ample account of the process used in working the gold ores in Spanish South America. A sufficient quantity of water is procured to wash them. A stream is made to carry off the earth, and every lighter substance. Negro slaves, dispersed on the banks, throw in fresh earth; while others, standing in the brook, work it about with their feet and hands. Care is taken to lay pieces of wood across the current of the water, to retain the lighter particles of the metal. This work is

\* For a very full account of the treatment of auriferous sands, the following works may be consulted:—1. The Memoir of Mr. Reaumur on the Auriferous Sands of France, printed among those of the Academy for the year 1718. 2. The Memoir of Mr. Guettard on the Ariege, inserted in the volume for 1761. 3. The Memoir upon the Gold which is obtained from the Ariege in the county of Foix, by the Baron de Dietrich. In this last work, the various processes are discussed; and this celebrated mineralogist proposes others more economical and advantageous.



continued for a month, and even for years together. When it is proposed to terminate it, the water is turned off; and then, in presence of the master, the workmen take up the sand with wooden vessels, in the form of shallow funnels, of one foot in diameter, at the bottom of which is an aperture of one inch in width. This dish is filled with sand; and by a circular motion the lighter substances are caused to flow off, while the heavier settle to the bottom. The platina is afterwards separated grain by grain, with the blade of a knife, upon a smooth board. The rest is amalgamated, first by working with the hands, and afterwards with a wooden pestle in mortars of guaiacum wood; after which the mercury is separated from the gold by fire.

The Baron de Born has reduced the method of working all the ores of silver and gold to one single process. The account which he has given of this process in his work, may be reduced to the following operations:

1. The mineral is pounded, divided, and sifted.
2. It is properly roasted.
3. It is mixed with muriate of soda, water, and mercury; and agitation is used to facilitate the amalgamation.
4. The mercury is expressed from the amalgam.
5. The expressed mercury is exposed to distillation.
6. The silver is refined by the cupel.

These operations were first executed at Schemnitz in Hungary, and afterwards at Joackimstal in Bohemia, in the presence of the greatest mineralogists in Europe, sent thither by the various sovereigns of Europe.

The muriate of soda is used to decompose the sulphates produced by the calcinations.

To determine the fineness of gold with accuracy, the purest is supposed to be twenty-four carats, and these carats are divided into thirty-second parts; the carat is always represented by a grain poids de marc.

The law directs the operations to be performed upon twenty-four grains of gold, tolerates twelve, and prohibits six, on account of the difficulty of appreciating the divisions which result from these small quantities.

In the parting assay, very pure silver must be made use of. This is mixed with the gold in the proportion of four to one, which has occasioned the name of Quartation to be



given to the process. Mr. Sage has found that two parts and a half of silver to one of gold form the mixture most proper for making the cornet of assay. The two metals are wrapped up in a thin piece of lead four times the weight of the gold, and this mixture is put into the cupel when it is very hot. The result of the cupellation is a button containing fine gold and fine silver. This is flattened, lamellated, and rolled up into a spiral; put into a small matraass, and six gros or drams of pure nitric acid, at thirty-two degrees of concentration, are poured on it. As soon as the matraass is heated, the metal becomes brown, the silver is dissolved, and much red vapours are disengaged. At the end of fifteen minutes the solution is decanted; and an ounce of very pure acid, rather more concentrated, is poured on, to carry away the last portions of silver. This solution is decanted, after a digestion of fifteen or twenty minutes; at which period warm water is added, and the cornet is washed until the water comes off tasteless. It is then dried in a crucible, weighed, and the fineness judged by the diminution of its weight.

Schindlers and Schutler have maintained that gold always retains a small quantity of silver, which they have called the *Interhalt*, or *Surplus*. Mr. Sage found a sixty-fourth part of a grain in the best conducted assay.

In order to separate the silver which is dissolved in the nitric acid, this solution is diluted with a considerable quantity of water, and flat pieces of copper are plunged in it; which precipitate the silver, as we have observed in treating of the solution of silver.

Gold, exposed to fire, becomes red-hot before it melts. When melted it suffers no alteration\*. Kunckel and Boyle kept it in a glass-house furnace for several months without change.

Homburg has never the less observed that this metal, exposed to the focus of the lens of Tschirnaus, smoked, was volatilized, and even vitrified in part. Mr. Macquer has verified this observation by the mirror of Mr. De Trudaine; he observed the gold fume, become volatilized, and covered

\* Gold, when fused by a strong heat, is of a beautiful green colour during the fusion.

with a dull pellicle, which constituted a violet-coloured oxide towards the middle.

Gold is not attacked by the sulphuric acid.

The nitric acid appears to have a real action upon it. Brandt is the first who announced the solution of gold by this acid. The experiments were made in the presence of the King of Sweden, and verified by his Academy. Messrs. Scheffer and Bergmann have confirmed the assertion of Brandt; and Mr. Sage afterwards published a series of experiments on this subject. I am convinced, from my own experiments, several times repeated, that the purest nitric acid attacked gold in the cold, and dissolved a sixty-fourth part of a grain. When very pure nitric acid is boiled upon gold equally pure, the solution may be ascertained in three ways—1. By the diminution of the weight of the metal. 2. By evaporation of the acid; in which case a purple spot remains at the bottom of the evaporatory vessel. 3. By the parting operation, by means of a plate of silver put into the liquor. In this case black flocks are in a short time disengaged, which consist of the gold itself. These phenomena appear to announce a true solution; and not a simple division or suspension, as was supposed.

The quantity of gold dissolved appeared to me to vary according to the strength of the acid, the time of the ebullition, and the thickness of the metallic body.

The nitro-muriatic acid, and the oxygenated muriatic acid, are the true solvents of gold. These acids attack it with greater energy in proportion as they are more concentrated, and as the surface of the gold is larger. The solution may likewise be accelerated by heat.

This solution has a yellow colour, is caustic, and tinges the skin of a purple colour. If it be properly concentrated, it affords yellow crystals, resembling topazes, which affect the form of truncated octahedrons. These crystals are a true muriate of gold, according to Messrs. Bergmann, Sage, &c. If the solution of gold be distilled, a red liquor is obtained, which consists of the muriatic acid, coloured by a small quantity of gold which it has carried over. This fluid was distinguished by the adepts under the name of Red Lion.

Gold may be precipitated from its solution of several colours, according to the nature of the substances employed

to make the precipitation. Gold is precipitated by lime and magnesia in a yellow powder, in which the gold exists nearly in the metallic state; a slight degree of heat only being necessary to convert it to that state.

The alkalis likewise precipitate gold in the form of a yellowish powder; and the precipitate is soluble in the sulphuric, nitric, and muriatic acids. These concentrated solutions suffer the gold to precipitate; crystals have not been obtained from them.

If ammoniac be poured on a yellowish solution of gold, the colour disappears; but, at the end of a certain time, small flocks are disengaged, which become more and more yellow; and gradually subside to the bottom of the vessel. This precipitate, being dried in the shade, is known by the name of *Fulminating Gold*; a denomination which it has obtained on account of its property of detonating, when gently heated.

Ammoniac is absolutely necessary to produce this effect.

The experiments of several chemists have taught us—  
1. That, by gently heating fulminating gold in copper tubes, one extremity of which was plunged in the pneumat-chemical apparatus by the assistance of a syphon, alkaline gas is obtained, and the precipitate is deprived of its fulminating property: this fine experiment was made by Mr. Berthollet.  
2. Bergmann has observed that, by exposing fulminating gold to a gentle heat, incapable of causing it to fulminate, it becomes deprived of that property.  
3. When the gold is made to fulminate, in tubes whose extremities are inserted under a vessel filled with mercury, the product is nitrogene gas, and some drops of water.  
4. By triturating fulminating gold with oily substances, it is deprived of its property of fulminating.

From these established facts, it is evident that fulminating gold is a mixture of ammoniac and oxide of gold. When this mixture is heated, the oxigene is disengaged at the same time with the hydrogenic of the alkali. These two gases take fire by simple heat, detonate, and produce water; the nitrogene gas then remaining alone. From these principles it ought to follow, that oily substances which combine with the oxigene, acids which seize the alkali, or a gentle and long-continued heat, which volatilizes the two principles without



inflaming them, ought to deprive this preparation of its property of fulminating.

The nitrous sulphur which Mr. Baumé supposed to be formed, in his explanation of this phenomenon, does not exist; for the solution of the oxide of gold by the sulphuric acid, when precipitated by ammoniac, affords a fulminating precipitate.

Gold is precipitated from its solution by several metals, such as lead, iron, silver, copper, bismuth, mercury, zinc, and tin. This last precipitates it instantly in the form of a powder, distinguished by the name of the Purple Powder of Cassius. This precipitate is much used in porcelain manufactories. Some very good observations on this preparation may be seen in the Dictionary of Macquer.

Gold may likewise be precipitated from its solution by ether: this liquor seizes the gold in a moment, and sometimes instantly revivifies it. I have seen the gold form a stratum at the surface of the liquor, and the two fluids no longer contained a particle.

The sulphures of alkali dissolve gold completely. Nothing more is necessary for this purpose, than quickly to fuse a mixture of equal parts of sulphur and pot-ash with one-eighth of the total weight of the gold in leaves. This substance may then be poured out, pulverized, and dissolved in hot water. The solution has a yellowish green colour. Stahl affirms that Moses dissolved the golden calf by a similar process; and that, though the beverage must have been of a disagreeable taste, this circumstance was an additional reason for preferring the method, in order that the Israelites might longer retain their disgust for idolatry.

Gold unites with most of the metals.

Arsenic renders it brittle, as well as bismuth, nickel, and antimony. All these semi-metals render it white and eager.

Gold unites very well with tin and lead. These two metals deprive it all of its ductility.

Iron forms a very hard alloy with gold, which may be employed to much greater advantage than pure gold.

Copper renders it more fusible, and communicates a reddish colour to it. This alloy forms money, gold plate, and toys.

Silver renders it very pale. This alloy forms the green gold of goldsmiths.



Gold is employed in a variety of purposes. It is entitled, by the first rank which it holds among metals, to the most noble uses.

As its colour is agreeable to the eye, and is not subject to tarnish, it is used in ornaments, or as toys; for which purpose it is wrought into a thousand forms.

For some purposes it is drawn into very fine wire, and used in embroidery. For other purposes it is extended into leaves so extremely thin, that the slightest breath of wind carries them away: in this form it is applied upon wooden articles by means of size.

For other purposes it is reduced into a very fine powder; in which case it is called Ground Gold, Shell Gold, Gold in Rags, &c.

The ground gold is prepared by levigating the clippings of gold leaf with honey, washing them with water, and drying the particles which subside.

Shell gold consists of ground gold mixed with a mucilaginous water.

In order to make the gold in rags, pieces of linen are steeped in a solution of gold, afterwards dried, and then burned. When it is required to use them, a wet cork is dipped in wood ashes, and rubbed upon such articles of silver as are intended to be gilded.

For some purposes it is amalgamated with mercury. This amalgam is applied upon copper, the surface being previously well cleared. It must be spread very even, and the mercury driven off by heat. This forms the *or moulu*.

A coating of gilders wax is laid over the gold thus applied. This is made with red bole, verdigris, alum, and sulphate of iron, incorporated and fused with yellow wax. The piece is heated a second time, to burn off the wax.

Gold was formerly used in medicine. This remedy was much in fashion in the fifteenth century. Its goodness has at all times been proportioned to the dearth of the drug. Bernard de Palissy exclaimed strongly against the apothecaries of his time, who demanded ducat gold from the sick to put into their medicines, under the pretence that the purer the gold the more speedy would be the restoration of the health of the patient.

As this metal is highly valued, the rage of forming it constituted a known sect, under the name of Alchemists, which may be divided into two classes. The one very ignorant, frequently unprincipled, and most commonly uniting both qualities, suffered themselves to be imposed on by certain phenomena, such as the increase of weight of metals by calcination, the precipitation of one metal by another, and the yellow colour which some bodies, and certain preparations affect. They grounded their notions on certain vague principles concerning the formation of bodies, their common origin, their seeds, &c.

It is this sect which has caused alchemy to be defined, *ars sine arte, cujus principium est mentiri, medium laborare, tertium mendicare*. These alchemists, after having been themselves the dupes for a considerable time, always endeavoured to impose on others; and there are a thousand tricks and impositions related of this class of men, which deserves only to be despised and pitied.

There is another class of alchemists which do not deserve to be made the object of public derision and contempt. This is formed of celebrated men, who, grounding their ideas on the received principles have directed their researches towards this object. This class of men is valuable on account of their genius, probity, and conduct. They have formed a language, held scarcely any communication but with each other, and have at all times distinguished themselves by their austere manners, and their submission to Providence. The celebrated Becher is a name which alone suffices to render this sect respectable. The following passage, extracted from Becher, exhibits an idea of their language, and manner of proceeding in this study.

“*Fac ergo ex lunâ et sole mercurios, quos cum primo ente sulphuris præcipita, præcipitatum philosophorum igne attenua, exalta, et cum sale boracis-philosophorum liquefac et fige donec sine fumo fluat. Quæ, licet breviter dicta sint, longo tamen labore acquiruntur et itinere, ex arenoso namque terrestri Arabico mari, in mare rubrum aqueum, et ex hoc in bitumineum ardens mare mortuum itinerandum est, non sine scopulorum et voraginum periculo, nos, Deo sint laudes, jam appulimus ad portum.*” Becher, *Phys. Sub. i. f. v. cap. iii.* page 461. in 8vo. *And elsewhere*, “*Concludo*

enim, pro thesi firmissima, asinus est qui contra alchymiam loquitur, sed stultus et nebulo qui illam practicè venalem exponit."

The enlightened alchemists have enriched chemistry with most of the products which were known before the late revolution. Their knowledge and their indefatigable ardour put them in the situation of profiting by all the interesting facts which offered themselves.

God forbid that I should induce any person to enter into this path. I would use every effort to prevent any one from engaging in this research, so full of disappointment, and so dangerous to attach the mind to it. But I am of opinion that the alchemists have been too lightly treated; and that this sect, which on many accounts is worthy of commendation, has not received the esteem and gratitude it is entitled to.

In addition to these reasons, I must observe that chemical phenomena become so wonderful; the torch of analysis has enlightened us to such an extent: we now decompose and reproduce so many substances, which ten years ago were considered with equal probability as indecomposable as gold is now thought to be; that no chemist can take upon him to affirm that we may not arrive at the art of imitating nature in the formation of metals.

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## CHAPTER XV.

### *Concerning Platina.*

WE were unacquainted with platina until the year 1748. It is to Don Antonio Ulloa, who accompanied the French Academicians in their famous voyage to Peru, to determine the figure of the earth, that we are indebted for our first notions of this metal.

Charles Wood, who had himself brought this metal from Jamaica, made experiments upon it, which are related in the Philosophical Transactions for the year 1749 and 1750.

Since that time, all the chemists in Europe procured this metal. Messrs. Scheffer in Sweden, Lewis in England, Margraff in Prussia, Macquer, Baumé, De Buffon, De



Milly, De Lisle, De Morveau, have successively made researches on this substance; and we are indebted for great part of our present knowledge of this metal to the Baron de Sickengen.

Platina has hitherto been found only in the metallic state. Its form is that of small grains or flattened plates, of a livid white colour, intermediate between that of silver and iron: it is from this colour that it derived its name of Platina, or Little Silver. If the grains of platina be carefully examined, it is found that some of them are rounded, and others angular.

It has been found among the auriferous sands of South America, near the mountains of the districts of Novita and Cytara. These two metals are almost constantly accompanied by a ferruginous sand obedient to the magnet. The platina of commerce usually contains a small quantity of mercury, arising from the amalgamation which the ore has undergone in extracting the gold. When it is required to have platina in a very pure state, it must be exposed to heat, to drive off the mercury; and magnetical parts, and the iron, must be sorted out with the magnet. Platina itself is slightly attracted by the magnet. M. L. affirms, in a Memoir read to the Academy of Sciences at Paris in the year 1785, that the lighter pieces of platina only are attracted by the magnet, and that they cease to be acted on when they exceed a certain size. The largest piece of platina which has been seen, is of the size of a pigeon's egg. It must be in the possession of the Royal Society at Bisca.

M. L. affirms that platina is malleable in its natural state; and he passed it through the flattening mill in the presence of Messrs. Tillet and Darcet.

Platina undergoes no alteration by exposure to the air; and fire alone does not even appear to possess the power of changing it. Messrs. Macquer and Baumé kept it several days in a glass-house furnace, without its grains having suffered any other change than that they were slightly agglutinated. It has nevertheless been ascertained that heat, kept up for a long time, tarnishes its surface, and increases its weight. Margraff formerly made this observation.

Platina, exposed to the focus of the burning mirror of Mr. De Trudaine, fumes and melts. This metal may be hammered like gold and silver. It may likewise be fused upon



charcoal, by the assistance of oxygenous gas. This substance resists the action of the acids, such as the sulphuric, the nitric, and the muriatic acids; it is soluble only in the oxygenated muriatic and the nitro-muriatic acids. One pound of the latter, digested on an ounce of platina, first assumes a yellow colour, then an orange colour, and lastly a very obscure brown. This solution tinges animal substances brown; it spontaneously deposits small irregular fawn coloured crystals; but, if it be concentrated, larger crystals are obtained, sometimes of an octahedral form, as Bergmann has observed. The muriate of platina is scarcely caustic, though sharp; it fuses in the fire, gives out its acid, and leaves an obscure grey oxide.

The sulphuric acid, poured on this solution, forms a precipitate of a dark colour; the precipitate occasioned by the muriatic acid, is yellowish.

The alkalis precipitate platina from its solution; but, if it be gradually precipitated by pot-ash, the precipitate is dissolved by the alkali in proportion as it is formed.

A solution of the muriate of ammoniac, poured into a solution of platina, forms an orange-coloured precipitate, which is a true saline substance, totally soluble in water. This precipitate has been fused by Mr. De Lisle in a common fire (of a furnace). The result of the fusion is platina, still altered by some portion of saline matter; for it does not acquire ductility but by exposure to a much stronger heat.

The property which the muriate of ammoniac possesses of precipitating platina, affords a very simple method of ascertaining the mixture of this metal with gold: so that the fear of this alloy, which had alarmed the Spanish ministry so much as to occasion them to forbid its being wrought, does not at present exist, as we possess a simple method of ascertaining the fraud: and it is much to be wished that this very precious metal should be restored to the arts, to which it cannot but be very useful, by its brilliancy, its hardness, and its unchangeable nature.

The process of Mr. De Lisle to fuse platina, was published in 1774. Mr. Achard published a simpler method, nearly at the same time: it consists in taking two gros of platina, two gros of the white oxide of arsenic, two gros of the acidulous tartrate of pot-ash, and putting them into a crucible well

luted. This is to be exposed for an hour to a violent fire, which fuses the platina; but it is brittle, and whiter than ordinary platina. It is then to be exposed to a considerable heat under a muffle; by which means all the arsenic which was combined with the platina is dissipated, and this metal left in a state of purity. Vessels of platina may be formed, by filling clay moulds with the alloy of platina and arsenic; and exposing the mould in the muffle, to dissipate the semi-metal.

Mr. De Morveau substituted the arseniate of pot-ash to advantage, instead of arsenic; and he had already fused platina with his vitreous flux, made of pounded glass, borax, and charcoal.

Mr. Pelletier fused platina, by mixing it with phosphoric glass and charcoal. The phosphorus then unites with the platina; and the phosphure of platina is exposed to a degree of heat sufficient to volatilize the phosphorus.

Mr. Baumé advises to fuse platina with a slight addition of lead, bismuth, antimony, or arsenic; and to keep the alloy in the fire a long time, to dissipate the metals which have facilitated the fusion.

Platina may likewise be fused with a metal soluble in an acid: the mixture being pulverized, the alloyed metal may be dissolved; and the powder of platina may then be fused with the flux of De Morveau.

Instead of using a soluble metal, a calcinable metal may be employed, and treated as before.

The cubic foot of crude platina weighs 1092 livres 1 ounce 7 gros 17 grains; platina purified and fused weighs 1365 livres; and purified platina forged weighs 1423, 8, 7, 64.

Most of the neutral salts have no perceptible action upon platina. The results of several curious experiments may be seen in the Memoirs of Margraff.

The nitrate of pot-ash alters platina, according to the experiments of Lewis and Margraff. Dr. Lewis, by heating a mixture of one part of platina and two parts of this nitrate, during three times twenty-four hours, observed that the metal assumed a rusty colour. By diffusing the mixture in water, the alkali was dissolved; and the platina, deprived of all the soluble matter, is diminished one-third. The powder taken up by the alkali is the oxide of iron, mixed with the oxide of platina.

These experiments, as likewise the property which platina possesses of being acted on by the magnet, prove that it contains iron; and Mr. de Buffon has concluded that this metal is a natural alloy of gold and iron. But it has been objected that the artificial alloy of these two metals, made in every possible proportion, never resembles platina; that this metal departs more from the properties of gold in proportion as it is deprived of iron: so that it is considered as a truly peculiar metal.

This metal is capable of being alloyed with most of the known metals.

Scheffer first affirmed that arsenic rendered it fusible.

Messrs. Achard and De Morveau have availed themselves of this property to fuse it, and compose vessels.

Platina easily unites with bismuth. The result is eager, very brittle, difficultly cupelled; and the result is a mass which has little ductility.

Antimony likewise facilitates the fusion of platina. The alloy is brittle; part of the antimony may be disengaged by fire; but a sufficient quantity remains in combination to deprive the platina of its weight and ductility.

Zinc renders this metal more fusible. The alloy is very hard; great part of the zinc may be volatilized by fire; but the platina always retains a small quantity.

This metal unites easily with tin. This alloy is very fusible, and flows clear; it is eager, and very brittle: but when the tin is in a large proportion, the alloy is ductile; its grain is coarse, and it becomes yellow by exposure to the air.

Lead unites very well with platina. A stronger heat is required to fuse this than the foregoing alloy. It is not ductile; is no longer capable of being absorbed by the cupel, the absorption only taking place when the lead is in excess; but the platina remains always united to a considerable portion of the metal. Nevertheless Messrs. Macquer and Baumé cupelled one ounce of platina and twenty ounces of lead, by exposing this alloy, for fifty hours, in the hottest part of the porcelain furnace at Seves. Mr. De Morveau had the same result in Mr. Macquer's wind-furnace: the operation lasted between eleven and twelve hours. Mr. Baumé observed that the platina obtained by this process possesses the power of being forged and soldered completely, without the assist-



ance of any other metal, which renders it a most valuable acquisition in the arts.

Dr. Lewis could not unite forged iron with platina; but having melted crude iron with this metal, there resulted an alloy so hard that the file could not touch it; it was ductile in the cold, but broke short when hot.

Copper and platina alloyed together form a very hard metal, which is ductile, while the copper predominates in the proportion of three or four to one: it takes a fine polish, and was not tarnished during the space of ten years.

Platina, alloyed with silver, deprives it of its ductility, increases its hardness, and tarnishes its colour. These two metals may be separated by fusion and repose. Lewis observed that the silver which is fused with platina is thrown up against the sides of the crucible with a kind of explosion: this phenomenon appears to be owing to the silver, as Mr. Darcet found it break porcelain balls in which it was inclosed, and out of which it was projected by the action of the fire.

Gold is not capable of being alloyed with platina but by the most violent heat: the colour of the gold is prodigiously altered, and the alloy possesses considerable ductility.

We know enough of the properties of this metal to presume that it will prove of the greatest use in the arts. Its almost absolute infusibility, and its unchangeableness, render it of extreme value to form chemical vessels, such as crucibles, and the like. The property of folding or welding without mixture, renders it preferable to gold or silver.

Its density and opacity render it likewise of great value for the construction of optical instruments; and the abbé Rochon has constructed a mirror whose effect greatly surpasses that of the mirrors before made of steel and other metals. This metal unites two qualities never before found in one and the same substance. Like other metallic mirrors, it reflects but one single image; at the same time that it is as unchangeable as the mirrors of glass.



## CHAPTER XVI.

*Concerning Tungsten and Wolfram.*

WE are acquainted with two minerals which may be distinguished by the generic title of Tungsten: the one white, and known by the name of Tungsten, or the Heavy Stone of the Swedes; the other known by the name of Wolfram by mineralogists. We shall examine each separately.

## ARTICLE I.

*Concerning Tungsten.*

Tungsten is a substance of an opaque white colour, very heavy, and of a moderate degree of hardness: its crystals are octahedrons. Its specific gravity is 6,0665, according to Brisson; from 4,99 to 5,8, according to Kirwan. The cubic foot weighs 424 livres 10 ounces 3 gros 60 grains.

When exposed without addition to the flame of the blow-pipe, it decrepitates without melting. With soda it is divided with a slight effervescence; is partly soluble in the native phosphate, or microcosmic salt; and affords a fine blue colour without the least appearance of red in the refracted light, as happens with cobalt. It is soluble in borax without effervescence.

Bergmann affirms that by pouring the muriatic acid upon pulverized tungsten the powder immediately assumes a fine bright yellow colour. To this character Scheele adds that of becoming blueish when boiled in the sulphuric acid.

This substance has a sparry appearance, and was long confounded with the white tin ore. It is found at Bittsburg, at Riddarhittan, at Marienburg, at Altemburg in Saxony, and at Sauberg near Ehrenfriedersdorff.

Mr. Raspe, in Crell's Annals for June 1785, gave an account of two mines of tungsten in the province of Cornwall, from which thousands of tons might be extracted. This philosopher obtained the metal in the proportion of about thirty-six livres the quintal. He adds that this metal contains little iron; that it is very fixed, and refractory in the fire; and that it acts on glass like the hardest steel.

Cronstedt arranges the tungsten among iron ores; and defines it to be *ferrum calciforme terrâ quâdam incognitâ intimè mixtum*.

Scheele has affirmed that it is a salt resulting from the combination of calcareous earth with a peculiar acid; which acid, combined with lime-water, regenerates tungsten.

Bergmann considers the acid earth of tungsten as a metallic acid.

Several processes are at present known for extracting the acid of tungsten.

1. Any desired quantity of this mineral is to be pulverized, and fused with four times its weight of carbonate of pot-ash, and poured out upon a plate of metal. The mass is then to be dissolved in twelve parts of boiling water. A white powder separates during the solution, and falls to the bottom of the vessel. This precipitate is a true carbonate of lime, mixed with a small quantity of quartz, and a portion of undecomposed tungsten. The carbonate of lime may be taken up from the precipitate by nitric acid; and the remaining tungsten being mixed with the former proportion of carbonate of pot-ash, is to be fused, dissolved, and by a repetition of these operations will at length be totally decomposed. The water in which the fused masses were washed, holds in solution a salt formed by the tungstic acid and the alkali made use of. If this solution be saturated with nitric acid, it seizes the alkali; the solution becomes thick; and a white powder falls down, which is the tungstic acid.

2. Scheele, the author of this first process, proposes a second, which consists in digesting three parts of weak nitric acid upon one of pulverized tungsten. This powder becomes yellow; the fluid is then decanted, and two parts of ammoniac are poured upon the yellow powder. The powder then becomes white; and in this way the repeated actions of the acid and the alkali are applied until the tungsten is dissolved. Out of four scruples, treated by Scheele in this manner, there were three grains of insoluble matter, which was a true quartz. By adding the prussiate of pot-ash to the nitric acid made use of, he obtained two grains of Prussian blue; pot-ash precipitated three of chalk; and the ammoniac uniting to the nitric acid, precipitated an acid powder, which is the true tungstic acid.

In this experiment the nitric acid seizes the lime, and uncovers the tungstic acid, which is seized by the alkali.

The muriatic acid may be substituted to advantage instead of the nitric acid, and even gives it a yellower colour.

Scheele and Bergmann considered this acid powder as the true tungstic acid in a state of purity. Messrs. Delhuyars have asserted that this acid was mixed with the acid made use of in obtaining it, and also with the alkali; they assert that the yellow powder which is uncovered by the digestion of the nitric acid, is the true acid oxide of tungsten without mixture.

The white powder which is obtained by decomposing the alkaline solution of tungsten by an acid, is acid to the taste, reddens the tincture of turnsole, precipitates the sulphure of alkali of a green colour, and is soluble in twenty parts of boiling water.

*Properties of the white powder obtained by decomposing the solution of the ore of tungsten by an acid.*

*Properties of the yellow matter obtained by fire or by acids.*

1. An acid taste, reddening the tincture of turnsole.

1. Insipid, reddening the tincture of turnsole.

2. Exposed to flame urged by the blow-pipe, it passes to a brown and black colour, without affording either fumes or signs of fusion.

2. Treated with the blow-pipe, it preserves its yellow colour in the external flame; but swells up, and becomes black, without fusing, in interior blue flame.

3. It is soluble in twenty parts of boiling water.

3. It is insoluble, but capable of becoming so divided as to pass through the filters.

4. It becomes yellow by boiling in the nitric and muriatic acids, and bluish in the sulphuric acid.

4. The three mineral acids have no action upon it.

From this comparison it appears that the acid is purer in the yellow powder than in the white; and the saline combinations of these two substances have confirmed Messrs. Delhuyars in their opinion.

The yellow acid, combined with pot-ash, either in the dry or humid way, forms a salt with excess of alkali. If a few drops of nitric acid be poured on this salt, a white precipitate is instantly formed, which is redissolved by agitation. When all the alkali is saturated, the solution is bitter; if more acid be poured in, the precipitate which falls down is no longer soluble. This precipitate, when well edulcorated,



is exactly of the same nature as the white powder we have spoken of. The experiments of Messrs. Delhuyars, and of Mr. De Morveau, prove very clearly that this white powder contains the acid of tungsten, a portion of the pot-ash with which it was before combined, and a small quantity of the precipitating acid.

It is therefore well proved that the yellow matter is the pure oxide, and the true tungstic acid. It is likewise very certain that this acid exists ready formed in the metal; and that its oxigene is afforded neither by the decomposition of another acid, nor the fixation of the oxigenous gas of the atmosphere; it appears to exist in the mineral, and to constitute a kind of salt of many principles.

The pure tungstic acid dissolves ammoniac; but the result is always with excess of alkali. This solution affords by evaporation small crystals, of a penetrating bitter taste, soluble in water, and then reddening blue paper. The alkali is easily separated; and these crystals return by calcination to the state of yellow powder, entirely similar to that which entered into its composition. If the calcination be made in closed vessels, the residue is of a deep blue colour; for the yellow colour does not appear unless the calcination be made in the open air.

The experiments of Mr. De Morveau permitted him to class the affinities of this acid in the following order, which is the same as that of the arsenical acid, lime, barytes, magnesia, pot-ash, soda, ammoniac, alumine, metallic substances.

## ARTICLE II.

### Concerning Wolfram.

Wolfram is of a blackish brown colour, sometimes affecting the form of an hexahedral compressed prism, terminated in a dihedral summit. These surfaces are frequently striated longitudinally. Its fracture is lamellated, foliated, and the leaves are flat, though rather confused. Externally it resembles schorl; but is not fusible, and is incomparably heavier.

Some mineralogists have taken it for an arsenical ore of tin; others for manganese, mixed with tin and iron. Messrs. Delhuyars, who made a strict analysis of it, found it to contain manganese 22, oxide  $13\frac{1}{2}$ , quartzose powder 2, yellow powder or tungstic acid 65.



The wolfram which was analysed by these chemists, came from the tin mines of Zinnwalde, on the frontiers of Saxony and Bohemia. Its specific gravity was 6,835.

Wolfram does not melt by the blow-pipe without addition, its angles being scarcely rounded. With the native phosphate, or microcosmic salt, it melts with effervescence, and affords a glass of an hyacinth colour.

It effervesces with Borax, and forms a greenish yellow glass in the blue flame. This glass becomes red in the external flame.

Pulverized wolfram upon which the muriatic acid is boiled, assumes a yellow colour like tungsten.

Messrs. Delhuyars fused in a crucible two gros of pulverized wolfram, and four gros of pot-ash. The fused mixture being poured out on a plate of copper, a black matter remained in the crucible; which, when welledulcorated, weighed thirty-seven grains, and was found to be a mixture of iron and manganese.

The mass which had been poured out was dissolved in water, filtered, and saturated with nitric acid. It afforded a white precipitate, absolutely similar to that obtained from tungsten by a similar process.

The process of Scheele, by the humid way, succeeds equally well, and even appeared to Messrs. Delhuyars to be more advantageous. They prefer the disengagement, by mere heat, of the ammoniac which holds the tungstic acid in solution. One hundred grains of wolfram, treated with the muriatic acid and ammoniac, afforded them sixty-five grains of a yellow powder, which is the pure acid.

This yellow acid powder unites with most of the metals. Messrs. Delhuyars relate the following facts;

1. One hundred grains of gold leaf, and fifty grains of the yellow matter, urged by a violent heat for three quarters of an hour, in a crucible lined with charcoal, afforded a yellow button, which crumbled in pieces between the fingers, and internally exhibited grains of gold, with others of a grey colour. This button weighed one hundred and thirty-nine grains; and was cupelled with lead, though with difficulty.
2. Similar proportions of platina and the yellow matter, treated in the same way (for an hour and a quarter), afforded a friable button, in which grains of platina were distinguish-

able, of a whiter colour than ordinary. It weighed one hundred and forty grains.

3. With silver, the yellow matter formed a button of a white greyish colour, rather spongy, which extended itself easily by a few strokes of the hammer; but on continuing them, it split in pieces. This button weighed one hundred and forty-two grains, and the mixture was perfect.

4. With copper, it afforded a button of a coppery red colour, inclining to grey, which was spongy, and considerably ductile. It weighed one hundred and thirty-three grains.

5. With crude or cast iron, of a white quality, it afforded a perfect button, whose fracture was compact, and of a greyish white colour. It was hard, brittle, and weighed one hundred and thirty-seven grains.

6. With lead, it afforded a button of an obscure grey colour, with very little brilliancy, spongy, very ductile, and splitting into leaves when hammered. It weighed one hundred and twenty-seven grains.

7. The button formed with tin was of a lighter grey than the preceding, very spongy, somewhat ductile, and weighed one hundred and thirty-eight grains.

8. The button of antimony was of a bright grey, rather spongy, brittle, and easily broken; it weighed one hundred and eight grains.

9. That of bismuth presented a fracture which, when seen in one direction, was of a grey colour, and metallic lustre; but in another direction it appeared like an earth without any lustre: but in both cases an infinity of pores were seen over the whole mass. It weighed sixty-eight grains.

10. The button formed with zinc was of a black greyish colour, and an earthy aspect, very spongy, and brittle: it weighed forty-two grains.

11. With common manganese it afforded a button of a blueish grey colour, and earthy aspect. Its internal part, examined with a lens, resembled an impure scoria of iron; it weighed one hundred and seven grains\*.

\* In Cullen's Translation of the Chemical Analysis of Wolfram, printed in London in 1785, I find the word *brown* in every place where M. Chaptal has used the word *gris*, or *grey*. Not having the original, I cannot speak with certainty; but from circumstances conclude this last to be right. T.

These experiments confirm the suspicion of the celebrated Bergmann; who, from the specific gravity of this substance, and its property of colouring the native phosphate and borate of soda, concluded that it was of a metallic nature.

The change of colour which accompanies its reduction, its increase of weight by calcination, its metallic aspect, and its uniting with other metals, are incontestable proofs of its metallic nature. The yellow matter must therefore be considered as a metallic oxide; and the button obtained by exposing this oxide to a strong fire, with powder of charcoal, is a true metal.

Messrs. Delhuyars having put one hundred grains of the yellow matter into a lined crucible well closed, and exposed it to a strong heat for an hour and a half, found upon breaking the crucible, when cold, a button which was reduced to powder between the fingers: its colour was grey. On examining it with the magnifier, an assemblage of metallic globules were seen, among which some were of the bigness of a pin's head, and when broken exhibited a metallic fracture resembling steel. It weighed sixty grains, and of course there was a diminution of forty. Its specific gravity was 17,6. Having calcined a part of it, it became yellow with  $\frac{1}{15}$  increase of weight. The nitric and the nitro-muriatic acid changed it into a yellow powder. The sulphuric and muriatic acids diminished its weight, and their solution let fall Prussian blue. The metallic grains always remained after the action of these acids. This metal shews various properties, which distinguish it from all others known. 1. Its specific gravity is 17,6. 2. It forms peculiar glass with the several fluxes. 3. It is almost absolutely infusible, much less fusible than manganese. 4. Its oxide is of a yellow colour. 5. It forms peculiar alloys with the known metals. 6. It is insoluble in the sulphuric, muriatic, nitric, and nitro-muriatic acids; and these two last convert it into an oxide. 7. The oxide combines with alkalis. 8. The oxide is insoluble in the sulphuric, nitric and muriatic acids, and assumes a blue colour with this last.

Wolfram ought to be considered as an ore, in which this metal is combined with iron and manganese, as Messrs. Delhuyars have proved.

## CHAPTER XVII.

*Concerning Molybdena.*

**TWO** substances have long been confounded together under the name of Black Lead Ore, Mineral Lead, Plumbago, and Molybdena, which the more accurate analysis of the celebrated Scheele has proved to be of a very different nature.

Molybdena cannot be confounded with the mineral of which black lead pencils are made, which is called Plumbago. The characteristic differences are sufficiently evident to leave no doubt on this subject.

Molybdena is composed of scaly particles, either large or small, and slightly adherent to each other. It is soft and fat to the touch, soils the fingers, and makes a trace of an ash-grey colour. Its aspect is blueish, nearly resembling that of lead. The mark it makes on paper has an argentine brilliancy; whereas those of plumbago are of a darker and less shining colour: its powder is blueish; by calcination it emits a smell of sulphur, and leaves a whitish earth. The nitric and the arsenical acids are the only acids which attack it effectually; it is soluble in soda with effervescence before the blow-pipe; it causes the nitrate of pot-ash to detonate, and leaves a reddish residue; when exposed to the flame of the blow-pipe in the spoon, it emits a white fume.

Plumbago is less fat, less granulated, and composed of small brilliant particles. It loses in the fire  $\frac{8}{100}$  of its weight, and the residue is an oxide of iron.

Molybdena has been found in Iceland, in Sweden, in Saxony, in Spain, in France, &c. that of Iceland is found in plates, in a red feld spar mixed with quartz.

Mr. Haßenfratz gave Mr. Pelletier samples of molybdena similar to those of Iceland, which he had collected in the mine named Grande Montagne de Chateau Lambert, near Tillot, where a copper mine was formerly wrought.

William Bowles appears to have found molybdena near the village of Real de Monasterio: it is in lanks of grit stone, sometimes mixed with granite.



The molybdena of Nordberg in Sweden is accompanied with iron that obeys the magnet.

The molybdena of Altemberg in Saxony nearly resembles that of Nordberg.

Mr. Pelletier analysed all these species; and his work may be consulted in the *Journal de Physique* for 1785; but the experiments we shall here relate were made with that of Altemberg.

Molybdena, exposed to heat on a test, becomes covered, after the space of an hour, with a white oxide; which, when collected by a process similar to that used with the sublimed oxide of antimony, has all the appearances of this last substance. The whole of the molybdena may by this means be converted into oxide. We are indebted to Mr. Pelletier for this fine experiment, which had escaped Scheele.

Molybdena is indestructible in close vessels, and prodigiously refractory, according to the experiment of Mr. Pelletier, made with balls of porcelain exposed to the most intense heat.

Molybdena treated with the black flux was not reduced, nor even deprived of its sulphur.

Molybdena fused with iron affords a button, which resembles cobalt: it unites likewise perfectly with copper; but when mixed with lead and tin, it renders them so refractory that the results are pulverulent and infusible alloys.

The oxide of molybdena obtained by calcination, or by the action of the nitric acid, is not reducible when treated with black flux, alkali, charcoal, or the other saline fluxes; nevertheless if the oxide of lead or copper be added, the metals which result are alloyed with a portion of molybdena, which may be separated.

The oxide of molybdena made into a paste with oil, dried by the fire, put into a lined crucible, and urged by a violent heat for two hours, afforded Mr. Pelletier a substance slightly agglutinated, which could be broken with the fingers. It was black, but perceptibly of a metallic aspect. When viewed with the magnifier, small round grains of a greyish metallic colour were seen, which are the metal of molybdena. It is prodigiously refractory: for the fire which Mr. Pelletier gave was stronger than that which Mr. Darcet used in the same forge to fuse platina and manganese.

1. Molybdena is calcinable, and passes to the state of a very white oxide. 2. It detonates with nitre, and the residue is an oxide of manganese mixed with alkali. 3. The nitric acid converts it into a white acid oxide. 4. The alkalis disengage hydrogenous gas from it in the dry way, and the residue is the oxide of manganese and alkali. 5. It alloys with the metals in different manners. Its alloys with iron, copper, and silver, are very friable. 6. When treated with sulphur it regenerates the mineral molybdena.

According to Mr. Kirwan, the mineral of molybdena contains fifty-five pounds sulphur, and forty-five metal. The iron is accidental.

To reduce the mineral molybdena to powder, Scheele directs that it be triturated in a mortar with a small quantity of sulphate of pot-ash. The powder is afterwards washed in hot water, to carry off the salt, and the molybdena remains pure.

This ore is a true pyrites, which, when treated with the blow-pipe, emits a white acid fume. But as this method affords only a small quantity of oxide, another method is used to obtain it. Thirty parts of nitric acid are distilled on one of powder of molybdena; care being taken to use a large retort, and to pour the acid on at several times, having previously diluted it with one-fourth of water. The receiver being luted on, the distillation is performed on the sand-bath. When the fluid begins to boil, a considerable quantity of nitrous gas comes over. The distillation being continued to dryness, there remains a powder, upon which an additional dose of nitric acid is poured; and this management is repeated until all the nitric acid has been used. At the end of the process there remains a residue as white as chalk, which is to be washed with water to carry off a small quantity of sulphuric acid, which is formed by the decomposition of the nitric acid upon the sulphur. After this edulcoration there remain six gros thirty-six grains of an acid powder, when the operation has been made with thirty ounces of nitric acid, and one ounce of molybdena. It is the molybdic acid.

The arsenical acid distilled from the mineral molybdena, likewise affords the molybdic acid.

It is evidently seen that its formation, like that of the arsenical acid, is owing only to the decomposition of the acid made use of, and the fixation of their oxigene on the metal employed.

This acid is white, and leaves a perceptibly acid and metallic taste on the tongue.

Its specific gravity compared with that of pure water is 3,460: 1,000, according to Bergmann.

It undergoes no alteration in the air.

It does not rise in sublimation, but by the assistance of the air.

It colours the native phosphate of a beautiful green.

If it be distilled with three parts of sulphur, the mineral molybdena is regenerated. This acid is soluble in five hundred and seventy times its weight of water at a mean temperature. The solution is very acid; decomposes the solutions of soap; precipitates the sulphures of alkali. It becomes blue and consistent by cold.

The concentrated sulphuric acid dissolves a large quantity of it. The solution assumes a fine blue colour, and becomes thick by cooling. This colour disappears by heat, and returns again as the fluid cools.

The muriatic acid dissolves a considerable quantity by the assistance of ebullition. If the solution be distilled, it leaves a residue of an obscure blue colour. By an increase of heat, white sublimate rises mixed with a little blue; the fuming muriatic acid passes over into the receiver. This sublimate attracts humidity, and is nothing but the molybdic acid volatilized by the muriatic.

This solution of the molybdic acid precipitates silver, mercury, and lead from their solutions in the nitric acid. It likewise precipitates lead from its solution of the muriate of lead, but not the other metals.

The molybdic acid takes barytes from the nitric and muriatic acids.

In the dry way it decomposes the nitrate of pot-ash, and the muriate of soda; and the acids pass over in the fuming state.

It disengages the carbonic acid from its combinations, and unites with the alkalis.

It even partly decomposes the sulphate of pot-ash by the assistance of a strong heat.

It dissolves several metals, and assumes a blue colour in proportion as it yields its oxigene to them.

The combinations of this acid with the alkalis are little known. Scheele however has observed, that fixed alkali renders this acid earth more soluble in water; that the alkali prevented the acid from rising; that the molybdite of pot-ash is precipitated by cooling in small granulated crystals.

The oxigene adheres but slightly to the molybdic base: for this acid boiled with the semi-metals does not fail to assume a blue colour.

Hydrogenous gas passed through it is sufficient to produce the blue colour.

Molybdena, as Mr. Pelletier has observed, has great resemblance in its chemical results to antimony; since, like that semi-metal, it is capable of affording by calcination an argentine oxide, capable of vitrification.



## PART THE FOURTH.

### CONCERNING VEGETABLE SUBSTANCES.

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#### INTRODUCTION.

THE mineral bodies upon which we have hitherto treated, possess no life, or vital principle, properly speaking; neither do they exhibit any phenomena dependant upon internal organization. The crystallization affected by substances of this kingdom, appears to be exceedingly different from the organization of living beings. It produces no advantage to the individual; and at most serves only to prove the great harmony of nature, which marks its several productions with constant and invariable forms. But the organization of vegetable and animal beings disposes those bodies in such a manner as is respectively the most proper to accomplish the two final purposes of nature; namely, the subsistence and reproduction of the individual\*.

It cannot be denied that vegetables are endued with a principle of irritability, which developes in them both sensation and motion: the motion is so evident in certain plants, that it may be produced at pleasure, as in the sensitive plant, the stamina of the opuntia, &c. The plants which follow the course of the sun; those which in hot-houses incline towards the apertures that admit the light; other plants which contract and shut up by the puncture of an insect; those whose roots turn out of their direct or original course to plunge themselves into a favourable soil, or water—have not these a degree of sensation of touch which may be compared to

\* For the development of these principles, see *La These sur l'Analyse Vegetal* supported at the schools of Montpellier by my scholar and friend, M. Riche.

the sensibility of animals? The difference of the secretions in various organs, supposes a difference in the irritability of each respective part.

The reproduction of vegetables is effected in the same manner as that of animals; and modern botanists have supported the comparison between these two functions in the most happy and conclusive manner.

Vegetables are nourished with air in the same manner as insects. This aliment is even of indispensable necessity, for without it the plant at last perishes: though the air which this order of beings requires, is neither of the same purity nor of the same kind.

The great difference which exists between vegetables and animals is, that the latter in general are capable of conveying themselves from place to place, in search of nourishment; whereas vegetables, being fixed in the same place, are obliged to take up in their own vicinity all such matters as are capable of nourishing them: and nature has provided them with leaves, to extract from the atmosphere the air and water of which they have need; while their roots extend to a distance in the earth, to take firm hold, as well as to receive other nutritive principles.

If we attend more minutely to the character of animals, we shall perceive that nature descends by imperceptible degrees from animals of the most complicated organization to vegetables; and we shall find it difficult to determine where one kingdom terminates, and the other begins. Chemical analysis is capable of marking the limits between these kingdoms in an imperfect manner. For a long time it was pretended that animal substances possessed the exclusive property of affording ammoniac, or the volatile alkali; but it is at present well known that certain plants likewise afford it. We may in strictness consider a vegetable as a being that participates in the laws of animal life, but in a less degree than the animal itself.

The difference which has been established between the vegetable and the mineral kingdoms, is much more striking. We may consider this last as a mass deprived of organization, and almost in an elementary state; receiving no modifications or changes but by the impression of external objects; capable of entering into combinations; of changing its nature; and

of re-appearing, or being reproduced with its original properties, at the pleasure of the chemist. The other kingdom, on the contrary, being endued with a particular life, which incessantly modifies the impression of external objects, decomposing them, and changing their nature, exhibits to us a series of functions regular throughout, and almost all of them inexplicable: and when the chemist has succeeded in depriving these bodies of their organization, and separating their principles, he finds it beyond his power to reproduce it by any re-union of the same principles.

In the mineral kingdom, we are justified in referring all the phenomena to the action of external bodies; and forces purely physical, or the simple laws of affinity, afford deductions sufficient to account for all its metamorphoses. In the vegetable kingdom, on the contrary, we are compelled to acknowledge an internal force which performs every thing, governs all the processes, and subjects to its designs those agents which have an absolute empire over the mineral kingdom.

The mineral possesses no evident life, no period which may be considered as the term of its perfection; because its various states are always relative to the purposes to which we intend to apply it. It does not appear either to grow or to be reproduced: at most it changes its form, but never by any internal determination; this is always the mere physical effect of the action of external objects. In those cases wherein the mineral exhibits marks of increase or vegetation, it is by the successive application of similar materials worn and transported by the waters. In these apparent vegetations we perceive neither elaboration or design: the law of affinities ever presides in these arrangements; and this law is the law of bodies void of life.

It is not therefore surprising that the chemical analysis should have made less progress in the vegetable than in the mineral kingdom, for it becomes more difficult in proportion as the functions are complicated: and in the vegetable kingdom the constituent parts are more numerous, at the same time that they are less easily distinguished by characteristic properties; and the methods of analysis hitherto employed are all imperfect; not to mention that the proceedings of chemists have likewise been conducted upon an erroneous principle.

All plants have hitherto been analysed either by fire or by menstruums. The first of these methods is very uncertain; for the action of fire decomposes combined bodies, alters their principles, forms new bodies by the combination of these separate elements, and extracts nearly the same principles from very different substances. Long experience has shewn the imperfection of this method. Messrs. Dodart, Bourdelin, Tournefort, and Boulduc have distilled more than fourteen hundred plants; and it was from the results of so extensive a work that Homberg deduced sufficient reasons to conclude that this method is erroneous. As a proof of his assertion, he quotes the analysis of cabbage and hemlock, which afforded the same principles by distillation.

The method by menstruums is somewhat more accurate, because it does not change the nature of the products: it has been even of greater advantage to medicine, by affording methods of separating the medicinal principle from certain vegetables. It has also afforded its assistance to extract other principles in all their purity, which are useful in the arts, or for the purposes of life; and it has given us more instruction concerning the nature of vegetable principles. But we cannot confine ourselves to this single method in the analysis of plants; and a considerable share of genius is required in the chemist, to vary his process according to the nature of the vegetable, and the character of the principle he is desirous of extracting.

A reproach of considerable weight may be urged against most of the chemists who have written upon the vegetable analysis: it is, that they have followed no order in their proceedings, nor attended to any regular distribution of the facts. They have confined themselves to indicate processes for extracting such or such substances, without connecting the whole with any system founded either on the methods of operating, on the nature of the products, or on the proceedings followed by nature in its own operations. I confess that, if a disquisition on the vegetable analysis were to be confined to the processes necessary to be known in extracting the several substances, the system of order and of method which I propose would be useless: but if it be an object to know the operation of nature, and to survey the vegetable kingdom like a philosopher, a naturalist, and a chemist, it is necessary to inspect the operations of nature herself among vegetables, and to follow as much as possible a plan which shall render us acquainted



with the plant under all these points of view: that which I have adopted appears to me to answer that purpose.

We shall begin by exhibiting a cursory account of the vegetable structure, in order that we may become better acquainted with the connection between its organization and the principles which we shall extract.

In the second place we shall attend to the development and increase of the vegetable. With this intention we shall shew the various principles which serve for its nourishment; and we shall follow their alterations in the vegetable œconomy, as much as we are enabled to do. We shall therefore of consequence examine the influence of the air, the soil, the light, &c.

In the third place we shall examine the results of the work of organization upon elementary substances; and for that purpose we shall teach the method of distinguishing the several constituent principles of vegetables: taking care to proceed in this examination according to that method which nature herself points out.

Thus we shall begin with the analysis of such products as we can extract without destroying the organization of the plant, and which are exhibited in a naked state by that organization; such as the mucilage, the gums, the oils, the resins, the gum resins, &c. We shall in the next place analyse such principles as cannot be collected but by destroying the organization of the plant; such as the fecula, the glutinous part, the sugar, the acids, the alkalis, the neutral salts, the colouring principles, the extractive matter, iron, gold, manganese, sulphur, &c.

We shall likewise attend to the prolific humours of vegetables; that is to say, the examination of such substances as, though necessary to life, are urged outwards to answer certain functions: the pollen and honey are of this kind.

We shall afterwards examine the humours which evaporate and escape by transpiration; such as oxygenous gas, the aqueous principle, the aroma, or odorant principle, &c.

And in the last place we shall shew the alterations to which vegetables are subjected after death. In order to proceed with regularity in a question of such great importance, we successively examine the action of heat, of the air, and of water, upon the vegetable, whether they act separately or together. This proceeding will render us acquainted with all the phenomena exhibited by vegetables in their decomposition.

## SECTION I.

Concerning the Structure of Vegetables.

**E**VERY vegetable exhibits in its structure—  
 1. A fibrous and hard mechanism, which supports all the other organs, determines the direction, and gives the proper solidity to the several plants and their parts. 2. A cellular tissue, which accompanies all the vessels, envelopes all the fibres, contorts itself in a thousand ways, and every where forms coverings and a net-work, which connect all the parts, and establish an admirable communication between them. We shall describe the several parts of plants in a very concise manner, and shall confine ourselves to the explanation and description of such organs as must necessarily be known with accuracy, before we can proceed to the analysis of plants.

## ARTICLE I.

Concerning the Bark.

The bark is the external covering of plants: its prolongations or extensions cover all the parts which compose the vegetable. We may distinguish three particular tunics, which may be separately detached and observed. The epidermis, the cellular tissue, and the cortical coatings.

1. The epidermis is a thin membrane, formed of fibres that cross each other in every direction: its texture is sometimes so thin, that the direction of its fibres may be seen by holding it against the light. This membrane is easily detached from the bark when the plant is in a vigorous state; and when it is dried the separation may be effected by steeping it in water. When the epidermis of a plant is destroyed, it grows again; but is then more strongly adherent to the rest of the bark, so as to form a kind of cicatrice.

This epidermis appears to be intended by nature to modify the impressions of external objects upon the vegetable; to furnish a great number of pores, which transmit or throw off the excretory products of vegetation; to protect the last or extreme ramification of the aerial or aqueous vessels, which

extract out of the air such fluids as are necessary for the increase of the vegetable; and to cover the cellular organ, which contains the principal vessels, and those glands in which the several fluids are digested and elaborated.

2. The cellular coating forms the second part of the bark. Its texture consists of vesicles and utricles, so very numerous, and so close together, as to form a continued coating. It is among these glands that the work of digestion appears to be performed; and the product of this elaboration is afterwards conveyed through the whole vegetable, by vessels propagated through all its parts and communications; even with the medullary substance or pith, by conduits that pass through the body of the tree, crossing the ligneous strata. In this net-work it is that the colouring matter of vegetables is developed: the light which penetrates the epidermis concurs in enlivening the colour: here likewise it is that oils and resins are formed, by the decomposition of water and the carbonic acid: and lastly it is from this reticular substance that those various products of the organization are thrown off or excluded, which may be considered as the feces of the vegetable digestion.

3. The coatings which lie between the external covering and the wood or body of the vegetable, and may be called the cortical coatings, are formed of laminae which themselves consist of the re-union of the common, proper, and air vessels of the plant. The vessels are not extended lengthwise along the stem, but are curved in various directions; and leave openings or meshes between them, which are filled by the cellular matter itself. Nothing more is necessary to shew the organization, than to macerate these coatings in water, which destroys the cellular substances, and leaves the net-work uncovered\*. The cortical coverings are easily detached from each other; and it is from their gross resemblance to the leaves of a book, that they have been called *liber*. In proportion as these coatings approach the ligneous body, they become hard; and at length form the external softer part of the wood, which workmen call the sap.

The bark is the most essential part of the vegetable, by means of which the principal functions of life, such as nutri-

\* This is most particularly seen in the *arbre à dentelle*, when the plant has been macerated in water.



tion, digestion, the secretions, &c. are performed. All plants, and particularly those which are hollow within, and whose products are totally changed by covering them with a different bark, prove evidently that the digestive force eminently resides in this part. The ligneous part is so far from being essential, that many plants are without it; such as the gramineous and the arundinaceous, and all plants that are hollow within. Grasses, properly speaking, have only the cortical part. We often see plants internally rotten, but kept in vigour by the good state of their bark.

## ARTICLE II.

### Concerning the Ligneous Texture.

Beneath the bark there is a solid substance, which forms the trunk of trees, and appears to be usually composed of concentric layers. The interior coatings or rings are harder than the exterior; they are older, and of a more firm and close grain. The hardest of these form the wood, properly so called, while the softer external rings constitute the sap. We may consider wood as being formed of fibres, more or less longitudinal, connected together by a cellular tissue, interspersed with vesicles communicating with each other; which diminish gradually towards the centre, where they form the pith. The pith is found only in young branches or plants, and disappears in plants of a certain age.

The vesicular tissue bears a great analogy with the glandular and lymphatic vessels of the human body: in both, the conformation and uses are the same. In the early age of plants and animals, the organs have a considerable expansion, because the increase of the individual is very rapid at that period. But, as age advances, the vessels become obliterated in both kingdoms; and it is observed that, in the white woods and fungi which abound with the vesicular substance, the growth is also very rapid.

## ARTICLE III.

### Concerning the Vessels.

The various humours of vegetables are contained in certain appropriated vessels, in which they enjoy a degree of motion that has been compared to the circulation in animals. It differs from it, however; because these humours



are not continually kept in equilibrio in the vessels by an inherent force, but receive in a more evident manner the impression of external agents. Light and heat are the two great causes which determine and modify the motion of the fluids and vegetables. These agents cause the sap to rise into the various parts, where it is elaborated in a manner correspondent to the functions of each; but it is not observed that it returns: so that the accession or flux of the humours in vegetables is proved, but the reflux does not appear to be perceptible.

Three kinds of vessels may be distinguished in vegetables: the common, or sap vessels; the proper vessels; and the air vessels, or tracheæ.

1. The sap-vessels convey the sap, or general humour, from which all the others are derived. This liquor may be compared to the blood in animals. These vessels are reservoirs from which the several organs extract the different juices, and elaborate them in a proper manner.

The sap vessels chiefly occupy the middle of plants and trees. They rise perpendicularly, though with deflexions sideways, so as to communicate with all the parts of the vegetable. They convey the sap into the utricles; whence it is taken by the proper vessels, in order that it may be duly elaborated.

2. Each organ is likewise provided with peculiar vessels, to separate the various juices, and to preserve them, without suffering them to mix with the general mass of humours. Thus it is that we find in the same vegetable, and frequently in the same organ, juices of different natures, and greatly differing in colour and consistence.

The vessels, whether common or proper, are retained in their several directions by the ligneous fibres; they are every where surrounded by the cellular tissue; they open, and pour their fluid into glands, into the cellular tissue, and into the utricles, to answer the various functions.

The utricles are small vessels or repositories which contain the pith, and frequently the colouring matter. They form a kind of repository in which the nutritive juice of the plant is preserved, and whence it is taken on occasion; in the same manner as the collection of marrow is formed in the internal part of the bones, whence it is afterwards

extracted when the animal is not sufficiently supplied with nutriment.

3. The tracheæ, or air vessels, appear to be the organs of respiration, or rather those which receive the air, and facilitate its absorption and decomposition. They are called tracheæ on account of the resemblance which is thought to exist between them and the respiratory organs of insects. In order to observe them, a branch of a tree is taken sufficiently young to break off short: after having cleared away the bark without touching the wood, the bough is broken by drawing the two extremities in opposite directions; the tracheæ are then seen in the form of small corkscrews, or vessels turned in a spiral direction. It is generally supposed that the large pores which are perceived in the transverse section of a plant, viewed in the microscope, are merely air vessels. It often happens that the sap is extravasated in the cavity of the tracheæ; and they appear incapable of serving any other purposes than that of conveying the air, at least for some time, unless a change takes place in the life of the plant.

#### ARTICLE IV.

##### Concerning the Glands.

Small protuberances are observed upon various parts of vegetables. These are glandular bodies whose form is prodigiously varied. It is more particularly upon this variation of form that Mr. Guettard has grounded his seven species. They are almost always filled with a humour, whose colour and nature are singularly varied.

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#### SECTION II.

##### Concerning the Nutritive Principles of Vegetables.

**I**F plants were to perform no other act than that of pumping the nutritive principles they contain out of the earth; if they did not possess the faculty of digesting, assimilating them, and forming different products, according to their nature, and the diversity of their organs; it would follow, as a consequence, that we ought to find in the earth all

those principles which analysis exhibits to us in vegetables: a conclusion which is contradicted by the facts; for we shall hereafter prove that the production of vegetable earth is an effect of the organization of plants, and that it owes its formation to them instead of communicating principles ready formed to those individuals. If it were true that plants did nothing but extract their component parts out of the earth, those plants which grow on the same soil would possess the same principles, or at least the analogy between them would be very great; whereas we find plants of very different virtues and flavours grow and flourish beside each other. In addition to this we may observe, that such plants as are raised in pure water—the fat plants, which grow without being fixed to the earth, provided they are placed in a moist atmosphere—the class of parasitical plants, which do not partake of the properties of those which serve to support them—prove that a vegetable does not derive its juices from the earth, on account of its being earth; but that it possesses an internal alterative and assimilating power, which appropriates to each individual the aliment which is suitable to it, at the same time that it disposes and combines that aliment to form certain peculiar principles. This digestive virtue will appear to be astonishingly perfect, when it is considered that the nutriment common to all vegetables is very little varied, since we know only of the water and air; and consequently that it possesses the power of forming very different products with these two simple principles. But from this circumstance, that the nutritive principles of plants are very simple, it must be presumed that, in the various results of digestion, or (which is the same thing) in the vegetable solids and fluids, there must be the greatest analogy; and that the differences are deducible from the proportion of the principles, and their more or less perfect combination, rather than from their variety. With this intention we shall carefully observe the transition from one principle to another; and shall explain the art of reducing them all to certain elementary or primitive substances, such as the fibrous matter, mucilage, &c.

## ARTICLE I.

Concerning Water, as a Nutritive Principle of Plants.

Every one knows that a plant cannot vegetate without the assistance of water: but it is not so generally known that this is the only aliment which the root draws from the earth; and that a plant can live, and propagate itself, without any other assistance than the contact of water and air. It appears to me, nevertheless, that the following experiments remove every doubt on this subject: Van Helmont planted a willow, weighing fifty pounds, in a certain quantity of earth covered with sheet lead: he watered it for five years with distilled water; and at the end of that time the tree weighed one hundred sixty-nine pounds three ounces and the earth in which it had vegetated was found to have suffered a loss of no more than three ounces. Boyle repeated the same experiment upon a plant, which at the end of two years weighed fourteen pounds more, without the earth in which it had vegetated having lost any perceptible portion of its weight.

Messrs. Duhamel and Bonnett supported plants with moss, and fed them with mere water: they observed that the vegetation was of the most vigorous kind; and the naturalist of Geneva observes, that the flowers were more odoriferous, and the fruit of a high flavour. Care was taken to change the supports before they could suffer any alteration. Mr. Tillet has likewise raised plants, more especially of the gramineous kind, in a similar manner; with this difference only, that his supports were pounded glass, or quartz in powder. Hales has observed that a plant which weighed three pounds gained three ounces after a heavy dew. Do we not every day observe hyacinths and other bulbous plants, as well as gramineous plants, raised in saucers or bottles containing mere water.

All plants do not demand the same quantity of water; and nature has varied the organs of the several individuals conformably to the necessity of their being supplied with this food. Plants which transpire little, such as the mosses and the lichens, have no need of a considerable quantity of this fluid; and accordingly they are fixed upon dry rocks, and have scarcely any roots; but plants which require a larger quan-



tity have roots which extend to a great distance, and absorb humidity throughout their whole surface.

The leaves of plants have likewise the property of absorbing water, and of extracting from the atmosphere the same principle which the root draws from the earth. But plants which live in the water, and as it were swim in the element which serves them for food, have no need of roots; they receive the fluid at all their pores: and we accordingly find that the fucus, the ulva, &c. have no roots whatever. The purer the water, the more salutary it is to plants. Mr. Duhamel has drawn this consequence from a series of well-made experiments, by which he has proved that water impregnated with salts is fatal to vegetation. Hales caused them to absorb various fluids, by making incisions in their roots, and plunging them in spirits of wine, mercury, and various saline solutions; but he was convinced that these were all poisons to the vegetables. Besides, if these salts were favourable to the plants, they would be again found in the individual which had been watered with a solution of them; whereas Messrs. Thouvenel and Cornette have proved that these salts do not pass into the vegetable. We must, nevertheless, except the marine plants, because the sea salt of which they have need is decomposed in them; and produces a principle which appears necessary to their existence, since they languish without it.

Though it is proved that pure water is more proper for vegetation than water charged with salts, it must not on that account be concluded that water cannot be disposed in a more favourable manner to the development of vegetables, by charging it with the remains of vegetable and animal decomposition. If, for example, the water be loaded with principles disengaged by fermentation or putrefaction, the plant then receives juices already assimilated to its nature; and these prepared aliments must hasten its growth. Independent of those juices already formed, the nitrogene gas, which constitutes one of the nutritive principles of plants, and is abundantly afforded by the alteration of vegetables and animals, must facilitate their development. A plant supported by the remains of vegetables and animals is in the same situation as an animal fed on milk only; its organs have less difficulty in elaborating this drink than that which has not yet been animalized.

The dung which is mixed with earths, and decomposed, not only affords the alimentary principles we have spoken of; but likewise favours the growth of the plant by that constant and steady heat which ulterior decomposition produces. Thus it is that Fabroni affirms his having observed the development of leaves and flowers, in that part of a tree only, which was in the vicinity of a heap of dung.

## ARTICLE II.

Concerning Earth, and its Influence in Vegetation.

Although it be well proved that pure water is sufficient for the support of plants, we must not consider the earth as of no use. Its utility resembles that of the placenta, which of itself affords no support to the life of the infant, but which prepares and disposes the blood of the mother to become a suitable nourishment: or it resembles, and has a similar utility with the various reservoirs which nature has placed in the body of man, to preserve the several humours, and emit them upon occasion. The earth imbibes and retains water; it is the reservoir destined by nature to preserve the elementary juice which the plant continually requires; and to furnish that fluid in proportion to its wants, without exposing it to the equally fatal alternatives of being either inundated or dried up.

We even see that, in the young plant or embryo, nature has not chosen to entrust the labour of digestion to the still feeble germen. The seed is formed of a parenchyma, which imbibes water, elaborates it, and does not transmit it to the germen until it is reduced into juice or humour. By insensible gradations this seed is destroyed; and the plant, become sufficiently strong, performs the work of digestion without assistance. In the same manner it is that we perceive the foetus supported in the womb of its mother by the humours of the mother herself; but, when it has seen the light, it receives for nourishment a fluid less animalized, its organs are gradually strengthened, and at length become capable of digesting a stronger and less assimilated nourishment.

But on this very account, that the earth is destined to transmit to the plant that water which is to support it, the nature of the soil cannot be a matter of indifference, but must be varied accordingly as the plant requires a more or

less considerable quantity of water, accordingly as it demands more or less in a given time, and accordingly as its roots extend to a greater or less distance. It may therefore be immediately perceived that every kind of earth is not suitable for every plant, and consequently that a slip cannot be grafted indifferently upon every species.

A proper soil is that—1. Which affords a sufficiently firm support to prevent the plant from being shaken. 2. Which permits the roots to extend themselves to a distance with ease. 3. Which becomes impregnated with humidity, and retains the water sufficiently that the plant may not be without it when wanted.—To answer these several conditions, it is necessary to make a proper mixture of the primitive earths, for none of them in particular possesses them. Siliceous and calcareous earths may be considered as hot and drying, the argillaceous as moist and cold, and the magnesian as possessing intermediate properties. Each in particular has its faults, which render it unfit for culture: clay absorbs water, but does not communicate it; calcareous earth receives and gives it too quickly: but the properties of these earths are so happily opposed, that they correct each other by mixture. Accordingly we find that, by adding lime to an argillaceous earth, this last is divided; and the drying property of the lime is mitigated, at the same time that the stiffness of the clay is diminished. On these accounts it is that a single earth cannot constitute manure; and that the character of the earth intended to be meliorated ought to be studied, before the choice of any addition is decided on. Mr. Tillet has proved that the best proportions of a fertile earth for corn, are three-eighths of clay, two-eighths of sand, and three-eighths of the fragments of hard stone.

The advantage of tilling consists in dividing the earth, aerating it, destroying useless or noxious plants, and converting them into manure, by facilitating their decomposition.

Before we had acquired a knowledge of the constituent principles of water, it was impossible to explain, or even to conceive, the growth of plants by this single aliment. In fact, if the water were an element, or indecomposable principle, it would afford nothing but water in entering into the nutrition of the plant, and the vegetable would of course exhibit that fluid only: but when we consider water as formed



by the combination of the oxygenous and hydrogenous gases it is easily understood that this compound is reduced to its principles; and that the hydrogenous gas becomes a principle of the vegetable, while the oxygen is thrown off by the vital forces. Accordingly we see the vegetable almost entirely formed of hydrogen. Oils, resins, and mucilage, consist of scarcely any thing but this substance; and we perceive the oxygenous gas escape by the pores, where the action of light causes its disengagement. This decomposition of water is proved not only in vegetable, but likewise in animal bodies. Rondelet (*Lib de Pisc.* lib. i. cap. 12.) cites a great number of examples of marine animals which cannot subsist but by means of water, by the very constitution of their organs. He affirms that he kept, during three years, a fish in a vessel constantly maintained full of very pure water: it grew to such a size, that at the end of that time the vessel could no longer contain it. He relates this as a very common fact. We likewise observe the red fishes, which are kept in glass vessels, are nourished, and grow, without any other assistance than that of the water properly renewed.

### ARTICLE III.

Concerning Nitrogenous Gas, as a Nutritive Principle of Plants.

Vegetables cannot live without air; but the air they require is not the same as is appropriated to man. Drs. Priestley, Ingenhousz, and Mr. Senebier, have proved that it is the nitrogenous gas which more particularly serves them for aliment. Hence it arises that vegetation is more vigorous when a greater quantity of those bodies which afford this gas by their decomposition are presented to the plant; these are, animals or vegetables in a state of putrefaction. As the basis of nitrogenous gas is unknown to us, it is difficult to conceive what may be its effect upon the vegetable economy, and we cannot follow it after its introduction into the vegetable. We do not find it again until the decomposition of the vegetable itself, when it re-appears in its gaseous form.

### ARTICLE IV.

Concerning the Carbonic Acid, as a Nutritive Principle of Vegetables.

The carbonic acid which is dispersed in the atmosphere,



or in waters, may likewise be considered as an aliment of plants; for these bodies possess the power of absorbing and decomposing it when its quantity is small. The base of this acid even seems to contribute to the formation of vegetable fibres: for I have observed that this acid predominates in the fungus, and other subterraneous plants. But by causing these vegetables, together with the body upon which they were fixed, to pass by imperceptible gradations from an almost absolute darkness into the light, the acid very nearly disappeared; the vegetable fibres being proportionally increased, at the same time that the resin and colouring principles were developed by the oxigene of the same acid. Senebier has observed, that the plants which he watered with water impregnated with the carbonic acid, transpired a much greater quantity of oxigenous gas; which proves a decomposition of the carbonic acid.

Vegetation may therefore be successfully employed to correct air too highly charged with carbonic acid, or in which the nitrogenous gas exists in too great a proportion.

#### ARTICLE. V.

##### Concerning Light, and its Influence on Vegetation.

Light is absolutely necessary to plants. Without the assistance of this principle they become pale, languish, and die. But it has not been proved that it enters as an aliment into their composition: at most it may be considered as a stimulus or agent which decomposes the various nutritive principles, and separates the oxigenous gas arising from the decomposition of water, or the carbonic acid, while their bases become fixed in the plant itself.

The most immediate effect of the fixation of the various substances, and the concretion of the liquids, which serve as the food of plants, is a sensible production of heat, which causes plants to participate very little in the temperature of the atmosphere. Dr. Hunter observed, by keeping a thermometer plunged in a hole made in a sound tree, that it constantly indicated a temperature several degrees above that of the atmosphere, when it was below the fifty-sixth division of Fahrenheit; whereas the vegetable heat in hotter weather, was always several degrees below that of the atmosphere.

The same philosopher has likewise observed, that the sap which out of the tree, would freeze at  $32^{\circ}$ , did not freeze in the tree unless the cold were augmented  $15^{\circ}$  more.

The vegetable heat may increase or diminish, by several causes, of the nature of disease; and it may even become perceptible to the touch in very cold weather, according to Mr. Buffon.

The heat produced in healthy vegetables, by the before-mentioned causes continually tempers the cold of the atmosphere: the evaporation which takes place through the whole body of the tree, continually moderates the scorching heat of the sun: and these productive causes of cold or heat are more effectual, in proportion as the heat or cold of external bodies acts with greater energy.

The property which plants possess of converting nitrogenous gas and carbonic acid into nourishment, establishes an astonishing degree of analogy between them and certain insects. It appears, from the observation of Frederic Garman (*Ephem. des Curios. Nat. Année 1675*), that the air may become a real food for the class of spiders. The larvæ of the ant, as well as of several insects of prey which live in the sand, increase in bulk, and undergo their metamorphoses without any other nourishment than that of the air. It has been observed that a great number of insects, particularly in the state of larvæ, are capable of living in the nitrogenous gas, mixed with carbonic acid, and transpiring vital air. The abbé *Fontana* has observed that several insects possess this property; and *Ingenbousz*, who is of opinion that the green matter which is formed in water, and transpires oxygenous gas by the light of the sun, is a cluster of animacula, has added to these phenomena. Insects have moreover the organ of respiration distributed over the whole surface of their bodies. Here therefore we observe several very astonishing points of analogy between insects and vegetables: and the chemical analysis adds still more to these resemblances, since insects and vegetables afford the same principles; namely, volatile oils, resins, disengaged acids, &c.

## SECTION III.

Concerning the Results of Nutrition, or the Vegetable Principles.

THE various substances which afford food to plants, are changed by the organization of the vegetable; from which there results a fluid generally distributed, and known by the name of Sap. This juice, when conveyed into the several parts of the plant, receives an infinity of modifications, and forms the several humours which are separated and afforded by the organs. It is to these principles chiefly that we are at present about to direct our attention; and we shall endeavour in our examination to follow the most natural order, by subjecting them to analysis in the same order as that in which nature presents them to us.

## ARTICLE II.

Concerning Mucilage.

Mucilage appears to constitute the first alteration of the alimentary juices in vegetables. Most seeds are almost totally resolvable into mucilage, and young plants seem to be entirely formed of it. This substance has the greatest analogy with the mucous fluid of animals. Like that fluid, it is most abundant in the earlier periods of life, and all the other principles appear to be derived from it; and in vegetables, as well as animals, its quantity becomes less in proportion as the increase of magnitude, or growth of the individual, becomes less, or ceases. Mucilage is not only the nutritive juice of plants and animals; but, when extracted from either, it becomes the most nourishing and wholesome food we are acquainted with.

Mucilage forms the basis of the proper juices, or the sap of plants. It is sometimes found almost entirely alone, as in mallows, the seeds of the wild quince, linseed, the seeds of thlaspi, &c. Sometimes it is combined with substances insoluble in water, which it keeps suspended in the form of an emulsion; as in the euphorbium, celandine, the convolvulus, and others. In other instances it is united with an oil and forms the fat oils. Frequently it is united with sugar;

as in the gramineous feeds, the sugar-cane, maize, carrot, &c. It is likewise found confounded with the essential salts, with excess of acid, as in barberries, tamarinds, sorrel, &c.

Mucilage sometimes constitutes the permanent state of the plant; as in the tremella, the conserva, some lichens, and most of the champignons. This existence in the form of mucilage is likewise seen in certain animals; such as the medusa or sea-nettle, the holothurion, &c.

The characters of mucilage are—1. Insipidity. 2. Solubility in water. 3. Insolubility in alcohol. 4. Coagulation by the action of weak acids. 5. The emission of a considerable quantity of carbonic acid, when exposed to the action of fire; at the same time that it becomes converted into coal, without exhibiting any flame. Mucilage is likewise capable of passing to the acid fermentation when diluted with water.

The formation of mucilage appears to be almost independent of light. Those plants which grow in subterraneous places abound with it. But light is required to enable mucilage to pass to other states; for, without the assistance of this principle, the same plants would obtain scarcely any consistence.

That which is called gum, or gummy juices, in commerce, is nothing but dried mucilage. These gums are three in number. They either flow naturally from the trunk of the tree which affords them, or they are obtained by incision of the bark.

1. Gums of the country, *Gummi nostras*.—This gum flows naturally from certain trees in our climate, such as the plum, the peach, the cherry-tree, &c. It first appears in the form of a thick fluid, which congeals by exposure to the air, and loses the adhesive and gluey consistence which characterizes it in the liquid state. Its colour is white, but more commonly yellow or reddish. When pure, it may be advantageously substituted for gum arabic, which is much dearer.

2. Gum arabic.—The gum arabic flows naturally from the acacia in Egypt and Arabia. It is even affirmed that it is not obtained from this tree only, but that the gum met with in commerce is the produce of several trees. The appearance of this gum is in round pieces, white and transparent, wrinkled without and hollow within; it is likewise found in round pieces variously contorted. This gum is easily soluble in water, and forms a transparent jelly called mucilage.



lage. It is much used in the arts and in medicine. It is mild, void of smell or taste, very well adapted to serve as the basis of pastils, and other preparations used as mitigating or softening remedies.

3. Gum adragant.—The gum adragant is nearly of the same nature as gum arabic. It flows from the adragant of Crete, a small shrub not exceeding three feet in height. It comes to us in small white tears, contorted, and resembling little worms. It forms with water a thicker jelly than gum arabic, and may be used for the same purposes.

If the roots of marshmallows or of the consolida, linseed, the kernels of the wild quince (coing), &c. be macerated in water for a time they afford a mucilage similar to that of gum arabic.

All these gums afford by distillation, water, an acid, a small quantity of oil, a small quantity of ammoniac or volatile alkali, and much coal. This sketch of analysis proves that mucilage is composed only of water, oil, acid, carbone, and earth; and shews that the various principles of the alimentary juices, such as water, the carbonic acid, an nitrogenous gas, are scarcely changed in this substance.

Gums are used in the arts and in medicine. In the arts they are applied to give a greater degree of consistence to certain colours, and to fix them more permanently upon paper; they are also used as a preparation to give a firmer body to hats, ribbons, taffetas, &c. Stuffs dipped in gum water acquire a lustre and brightness; but water, and the handling of these goods, soon destroy the illusion; and these processes are classed among those which nearly approach to imposition and deceit. Gum is likewise the basis of most kinds of blacking used for shoes, boots, and the like.

The gums are ordered in medicine as emollients. They compose the basis of many remedies of this kind. The mucilage of linseed, or of the kernels of wild quinces, is of value in allaying inflammations.

## ARTICLE II.

### Concerning Oils.

By common consent the name of Oil is given to fat unctuous substances, more or less fluid, insoluble in water, and combustible.

These products appear to belong exclusively to animals and vegetables. The mineral kingdom exhibits only a few substances of this nature, which possess scarcely any of the above properties, such as the unctuous property.

Oils are distinguished, relative to their fixity, into fat oils, and essential oils. We shall describe them in this article under the names of Fixed Oils and Volatile Oils. The difference between these two kinds of oils do not merely consist in their various degrees of volatility, but also in their habitudes with the several re-agents. The fixed oils are insoluble in alcohol, but the volatile oils are easily dissolved: the fixed oils are in general mild; while the volatile are acrid and even caustic.

It appears nevertheless that the oily principle is the same in both; but it is combined with mucilage in the fixed oils, and with the spiritus rector, or aroma, in the volatile oils. By burning the mucilage of fixed oils by distillation, they become more and more attenuated; the same may likewise be done by means of water, which dissolves this principle. By distilling volatile oil with a small quantity of water, by the gentle heat of a water bath, the aroma is separated; and this may be again restored by re-distilling it with the odorant plant which originally afforded it.

Volatile oil is usually found in the most odorant part of any plant. In umbelliferous plants it is found in the seed; in the geum, the root affords it; and in the labiated plants it is found in the branches and leaves. The similitude between volatile oils and ether, which appears to be merely a combination of oxigene and alcohol, proves that the volatile oils may be nothing but a combination of the fermentescible basis of sugar with oxigene. Hence we may form a notion how oil is formed in the distillation of mucilage and of sugar; and we shall no longer be surprised to find that the volatile oils are acrid and corrosive, that they redden blue paper, attack and destroy cork, and approach to the properties of acids. We shall now proceed to treat of fixed and volatile oils separately.

#### DIVISION I.

##### Concerning Fixed Oils.

Most of the fixed oils are fluid; but the greater number are capable of passing to the state of solidity, even by a

moderate degree of cold. There are some which constantly possess that form in the temperature of our climates; such as the butter of cacao, wax, and the pela of the Chinese. They all congeal at different degrees of cold. Olive oils become solid at  $10^{\circ}$  below zero of Reaumur; oil of almonds at the same degree; but nut-oil does not freeze in our climates.

The fixed oils possess a very evident degree of unctuousity, do not mix either with water or alcohol, are volatilized at a degree of heat superior to that of boiling water, and when volatilized they take fire by the contact of an ignited body.

The fixed oils are contained in the kernels of shell fruits or nuts; in the pippins, and sometimes in all the parts of fruits, such as olives and almonds, all whose parts are capable of affording them.

The oil is usually made to flow by expression out of the cellules which contain it: but each species requires a different management.

1. Olive oil is obtained by expression from the fruit of the olive tree. The process used by us is very simple. The olive is crushed by a mill stone, placed vertically, rolling upon an horizontal plane. The paste thus formed is strongly pressed in a press; and the first oil which comes out is called Virgin Oil. The marc or pulp is then moistened with boiling water; the mass is again pressed; and the oil which floats upon the water carries with it part of the parenchyma of the fruit, and a great part of the mucilage, from which it is difficultly cleared.

The difference in the kind of olive produces a difference in the oil; but the concurrent circumstances likewise establish other differences. If the olive be not sufficiently ripe, the oil is bitter; if it be too ripe, the oil is thick and glutinous. The method of extracting the oil has a very great influence on its quality. The oil mills are not kept sufficiently clean; the mill-stones, and all the utensils, are impregnated with a rancid oil, which cannot but communicate its flavour to the new oil. In some countries it is usual to lay the olives in heaps, and suffer them to ferment before the oil is drawn. By this management the oil is bad; and this process can only be used for oil intended for the lamp or for the soap-boiler.

2. Oil of almonds is extracted from that fruit by expression. For this purpose dry almonds are put into a coarse sack, and agitated rather strongly, to disengage an acrid powder which adheres to the skin. They are then pounded in a marble mortar into a paste, which is wrapped in a coarse cloth, and subjected to the press.

This oil is greenish and turbid when fresh, because the action of the press causes part of the mucilage to pass through the cloth; as it becomes older it is clearer, but is acrid by the decomposition of the same mucilage.

Some persons throw almonds into hot water, or expose them to steam, before they press them; but this addition of water disposes the oils to become rancid more speedily.

By this process the oil of all kinds of almonds, nuts, and seeds, may be extracted.

3. Linseed oil is extracted from the seed of the plant *linum*. As this seed contains much mucilage, it is torrefied before it is subjected to the press. This previous treatment gives the oil a disagreeable empyreumatic flavour; but at the same time deprives it of the property of becoming rancid, and renders it one of the most drying oils. All mucilaginous seeds, all kernels, and the seeds of henbane and of the poppy, ought to be treated in the same manner.

If a fat oil be distilled in a proper apparatus of vessels, the product is, phlegm; an acid; a fluid or light oil, which becomes thicker towards the end; much hydrogenous gas, mixed with carbonic acid; and a coaly residue, which affords no alkali. I have observed that the volatile oils afford more hydrogenous gas, and the fixed more carbonic acid: this last product depends on the mucilage. By distilling the same oil repeatedly, it is more and more attenuated, becomes very limpid and very volatile, with the only difference that it has required the peculiar odour communicated by the fire. The volatilization of the oil may be accelerated by distilling it from an argillaceous earth; by this means it is in a short time deprived of its colouring part: and the heavy oils which afford bitumens, when distilled once or twice from clay alone, such as that of Murviel, are rendered perfectly colourless. The ancient chemists prepared *oleum philosophorum* by distilling oil from a brick previously impregnated with it.

1. Oil easily combines with oxygen. This combination is either slow or rapid. In the first case, rancidity is the consequence; in the second inflammation.



Fixed oil exposed for a certain time to the open air, absorbs the oxygenous gas, and acquires a peculiar odour of fire, an acrid and burnt taste, at the same time that it becomes thick and coloured. If oil be put in contact with oxygen in a bottle, it becomes more speedily rancid, and the oxygen is absorbed. Scheele observed the absorption of a portion of the air before the theory was well ascertained. Oil is not subject to alteration in closed vessels.

It seems that oxygen, combined with the mucilage, constitutes rancidity; and that, when combined with the oil itself, it forms drying oil,

The rancidity of oils is therefore an effect analogous to the calcination or oxidation of metals. It essentially depends on the combination of pure air with the extractive principle, which is naturally united with the oily principle. We may carry this inference to demonstration, by attending to the processes used to counteract or prevent the rancidity of oils.

A. When olives are prepared for the table, every endeavour is used to deprive them of this principle, which determines their fermentation; and for this purpose various methods are used. In some places they are macerated in boiling water, charged with salt and aromatics; and, after twenty-four hours digestion, they are steeped in clear water, which is renewed till their taste is perfectly mild. Sometimes nothing more is done than to macerate the olives in cold water; but they are frequently macerated in a lixivium of quick-lime and wood ashes, after which they are washed in clear water. But in whatever manner the preparation is made, they are preserved in a pickle charged with some aromatic plant, such as coriander and fennel. Some persons preserve them whole; others split them, for the more complete extraction of their mucilage, and in order that they may be more perfectly impregnated with the aromatics.

All these processes evidently tend to extract the mucilaginous principle, which is soluble in water, and by this means to preserve the fruit from fermentation. When the operation is not well made, the olives ferment and change. If olives be treated with boiling water, to extract the mucilage, before they are submitted to the press, a fine oil will be obtained, without danger of rancidity.

B. When the oil is made, if it be strongly agitated in water, the mucilaginous principle is disengaged; and the oil may be afterwards preserved for a long time without change. I have preserved oil of the marc of olives, prepared in this manner, for several years, in open bottles, without any alteration.

C. The torrefaction to which several mucilaginous seeds are subjected before the extraction of the oil, renders them less susceptible of change, because the mucilage has been destroyed.

D. M. Sieffert has proposed to ferment oils with apples or pears, in order to deprive rancid oils of their acrimony. By this means they are cleared of the principle which had combined with them, but now becomes attached to other bodies.

Mucilage may therefore be considered as the seed of fermentation.

When the combination of the pure air is favoured by the volatilization of the oil, inflammation and combustion are then the consequence. To carry this combination into effect, the oil must be volatilized by the application of a heated body; and the flame which is produced is then sufficient to maintain the degree of volatility, and support the combustion. When a current of air is caused to pass through the middle of the wick and the flame, the great quantity of oxigene which must then necessarily pass, occasions a more rapid combustion. Hence it is that the light is stronger, and without smoke; for this is destroyed and consumed by the violent heat which is excited.

The lamps of Palmer are likewise entitled to our particular attention. By causing the rays to pass through a liquor coloured blue; he perfectly imitates the light of the day; which proves that the artificial rays require to be mixed with the blue, to imitate the natural: and the solar rays which pass through the atmosphere, may owe their colour to their combination with the blue colour which appears to predominate in the air.

If water be projected upon oil in a state of inflammation, it is known that extinction does not happen, because the water is decomposed in this experiment. If the product of the combustion of oil be collected, much water is obtained, be-

cause the combination of its hydrogen with oxygen produces that fluid.

Mr. Lavoisier has proved that one pound of olive oil contains,

Coal or carbone, 12 ounces, 5 gros, 5 grains;

Hydrogene, - 3 — 2 67.

The art of rendering oils drying, likewise depends on the combination of oxygen with the oil itself. For this purpose, nothing more is required than to boil it with oxides. If an oil be heated upon the red oxide of mercury, a considerable ebullition ensues, the mercury is reduced, and the oil becomes very drying: this is an observation of Mr. Puymaurin. The oxides of lead or copper are commonly used for this purpose. An exchange of principles takes place in this operation; the mucilage combines with the metal, while the oxygen unites with the oil.

Oil may likewise be combined with the metallic oxides by double affinity, after the manner of Berthollet. For this purpose a solution of soap is poured into a metallic solution. By this means a soap of a green colour is prepared with a sulphate of copper; and, with that of iron, a soap of a deep brown colour, of considerable intensity.

It appears that, in the combinations of fixed oils with the oxides of lead, a substance is disengaged, and swims at the top, which Scheele called the Sweet Principle, and seems to be simply mucilage.

2. Oil combines with sugar, and affords a kind of soap, which may be easily diffused in water, and kept suspended. The trituration of almonds with sugar and water, forms the *læ amygdale*, orgeat, and other emulsions. Combinations of this kind exist ready formed in the vegetable kingdom.

3. Oil unites readily with alkalis; and the result of this union is the well-known compound, soap. To this effect, potash or pure alkali may be triturated with oil, and the mixture concentrated by fire. The medicinal soap is made with oil of sweet almonds, and half its weight of pot-ash or caustic alkali. The soap becomes hard by standing.

To make the soap of commerce, one part of good soda of Alicant must be boiled with two of quicklime; in a sufficient quantity of water. The liquor is then to be strained through a cloth; and evaporated to that degree, that a phial which

contains eight of pure water, may hold eleven of the saline solution, which is usually called Soap Lye or Lees. One part of this lixivium, and two of oil, boiled together, till upon trial with a spatula it easily separates, and soon coagulates, form soap.

In most manufactories the lixivium is prepared without heat. Equal volumes of pounded soda of Alicant, and quicklime previously slacked, are mixed together. Water is thrown on this mixture, which filters through, and is conveyed into a proper vessel. Water is poured on till it passes through without acquiring any more salt. In this way these kinds of lyes are obtained, which differ in strength; that which passes first is the strongest, and the last is almost mere water. These are afterwards mixed with oil in boilers, where the mixture is favoured by heat. The weak lye is first added, and afterwards gradually the stronger; and the strongest is not added till towards the end of the process.

To make the soap marbled, they make use of soda in the mass, blue copperas, cinnabar, &c. according to the colour desired.

A liquid green or black soap is likewise made by boiling the lixivium of soda, pot-ash, or even wood ashes, with the marc of the oils of olive, of nuts, or of nape; or with fat, or fish oil, &c. The black soap is made in Picardy, and the green in Holland. The Marquis de Bouillon has proposed to make soaps with animal fat.

At Aniane, and in the neighbourhood of Montpellier, a soft soap is prepared with caustic lixivium of wood ashes, and the oil or the marc of olives.

If soap be exposed to distillation, the result is water, oil, and much ammoniac; and there remains in the retort a large quantity of the alkali used in the fabrication of the soap. The ammoniac which is produced in this experiment, appears to me to arise from the combination of the hydrogenous gas of the oil with the nitrogene, a constituent principle of the fixed alkali.

Soap is soluble in pure water; but it forms curds, and is decomposed in water abounding with sulphates: because the sulphuric acid seizes the alkali of the soap; while the earth combines with the oil, and forms a soap which swims at the surface.



Soap is likewise soluble in alcohol by the assistance of a gentle heat; and forms the essence of soap, or opodeldoc, which may be scented at pleasure.

Soaps are capable of combining with a larger quantity of oil, and rendering it soluble in water. Hence their property of cleansing cloths, linens, &c. They are used as deobstruents in medicine.

4. The fixed oils unite likewise with acids. Messrs. Achard, Cornette, and Macquer, have attended to these combinations. Achard gradually adds the concentrated sulphuric acid to the fixed oil; the mixture being triturated, a mass is obtained which is soluble in water and in alcohol.

The fuming nitric acid immediately turns the fixed oils black, and sets fire to such as are drying. It is in this case decomposed with a rapidity so much the greater, as the oil has a greater affinity with the oxygen. On this account it is that the inflammation of the drying oils is more easily effected than that of the others.

Those acids whose constituent parts adhere most strongly together, have but a very feeble action on oils; a circumstance which proves that the effect of acids upon oils is principally owing to the combination of their oxygen.

It is by virtue of this strong affinity of oils with oxygen, that they possess the power of reviving metals. The oxygen then quits the metal, and unites with the oils, which become thick and coloured. It likewise follows from hence that drying oils ought to be preferred for this use; and we find that practice agrees with theory in this respect.

## DIVISION II.

### Concerning Volatile Oils.

Fixed oil is combined with mucilage, volatile oil with the spiritus rector, or aroma; and it is this combination or mixture which constitutes the difference between them. The volatile oils are characterized by a strong smell, more or less agreeable; they are soluble in alcohol, and have a penetrating and acrid taste. All the aromatic plants contain volatile oil, excepting those whose smell is very transient, such as jessamine, violets, lilies, &c.

The volatile oil is sometimes distributed through the whole plant, as in the Bohemian angelica; sometimes it

exists in the bark, as in cinnamon. Balm, mint, and the greater absinthium, contain their oils in the stem and leaves; clicampane, the iris of Florence, and the caryophyllata, in the root. All the resinous trees contain it in their young branches; rosemary, thyme, and wild thyme, contain their essential oils in their leaves and buds; lavender, and the rose, in the calyx of their flowers; camomile, lemon, and orange trees, in the petals. Many fruits contain it through their whole substance, such as pepper, juniper, &c. Oranges and lemons in the zest and peeling which inclose them. The seed of umbelliferous plants, such as anise and fennel, have the vesicles of essential oil arranged along the projecting lines upon their skin: the nutmeg tree contains its essential oil in the nut itself.—See *L'Introduction à l'Etude du Regne Veg. par M. Buquet*, p. 209—212.

The quantity of volatile oil varies according to the state of the plant. Some afford most when green, others when dry; but the latter constitute the smallest number. The quantity likewise varies according to the age of the plant, the soil, the climate, and the time of extraction.

The volatile oils likewise differ in their consistence. Some are very fluid, as those of lavender, rosemary, and rue; the oils of cinnamon and saffrafras are thicker; there are some which constantly preserve their fluidity; others which become concrete by the slightest impression of cold, as those of aniseed and fennel: others again possess the concrete form, such as those of roses, of parsley, and of clicampane.

The volatile oils likewise vary in their colour. The oil of roses is white; that of lavender, of a light yellow: that of cinnamon, of a brown yellow; the oil of camomile is of a fine blue; that of millefoil, of a sea-green; that of parsley, green, &c.

The weight is likewise different in the different kinds. The oils of our climates are in general light, and swim upon water; others are nearly of the same weight; and others are heavier, such as the oils of saffrafras and of cloves.

The smells of essential oils vary according to those of the of the plants which produce them.

The taste of the volatile oils in general is hot; but the taste of the plant does not always influence that of the oil; for example, the oil of pepper has no acrimony, and that which is obtained from wormwood is not bitter.

We are acquainted with two methods of extracting the volatile oils—expression and distillation.

1. Those oils which are, as it were, in a naked state, and contained in projecting and visible receptacles, are obtained by expression. Such are those of citrons, oranges, cedrat, and bergamotte; the oil issues out of the skin of these fruits when pressed. It may therefore be procured by a strong pressure of the peeling against an inclined glass. In Provence and in Italy they are rasped; by which means the vesicles are torn, and the oil flows into the vessel destined to receive it: this oil suffers the parenchyma which goes along with it to subside, and becomes clear by standing.

If a lump of sugar be rubbed against these vesicles, it imbibes the volatile oils; and forms an oleo-saccharum, soluble in water, and very proper to give an aromatic flavour to certain liquids.

2. Distillation is the method most commonly used in the extraction of volatile oils. For this purpose, the plant or fruit which contains the oil is placed in the boiler or body of the alembic. A quantity of water is then poured in, sufficient to cover the plant, and the water is heated to ebullition. The oil which rises with this degree of heat, comes over with the water, and is collected at the surface in a particular receiver, called the Italian receiver, which suffers the surplus of water to escape by a spout issuing from the belly of the vessel, whose orifice is lower than that of the neck of the receiver; so that by this means the oil is collected in the neck, without a possibility of its escaping.

The water which passes over in distillation is more or less charged with oil, and the odorant principle of the plant, and forms what is known by the name of Distilled Water. These waters ought to be returned again into the cucurbit when the same kind of plant is again distilled; because, being saturated with oil, and the aromatic principle, they contribute to augment the ulterior product.

When the oil is very fluid or very volatile, it is necessary to annex a worm pipe to the alembic, and to have the precaution of keeping the water at a very cold temperature; but when, on the contrary, the oil is thick, the worm pipe must be removed, and the water of the refrigeratory kept at a moderate temperature. In the first way, the oils of balm,



mint, sage, lavender, camomile, &c. may be distilled; and, by the second, the oils of roses, of elicampane, of parsley, of fennel, of cumin, &c.

The oil of cloves may likewise be extracted by distillation per descensum, which is determined by applying the fire above the material.

Volatile oils are very subject to be adulterated, either by mixture with fat oils, or with other essential oils, such as that of turpentine, which is cheaper; or by mixing them with alcohol. In the first case the fraud is easily detected—

1. By distillation, because volatile oils rise at the heat of boiling water. 2. By causing blotting paper to imbibe some of the mixture, and exposing it to a degree of heat sufficient to drive off the volatile oil. 3. By means of alcohol, which becomes turbid and milky by the insolubility of the fixed oil.

The volatile oils which have a very strong smell, such as those of thyme and lavender, are often sophisticated by oil of turpentine. In this case the fraud may be discovered by soaking a small piece of cotton in the mixture, and leaving it exposed to the air a sufficient time for the smell of the good oil to be dissipated, and leave only that of the adulteration. The same end may be answered by rubbing a small quantity of the mixture on the hand, in which the peculiar smell of oil of turpentine is developed. These oils are likewise falsified by digesting the plant in oil of olive before distillation. In this manner the oil of camomile is prepared.

The very light oils, such as those of cedrat or bergamotte, are often mixed with a small quantity of alcohol. This fraud is easily detected by the addition of a few drops of water, which immediately become white, because the alcohol abandons the oil to unite with the water.

The volatile oils are capable of uniting with oxigene, with alkalis, and with acids.

1. Volatile oils absorb oxigene with greater facility than the fixed oils. They become coloured by the absorption, grow thicker, and pass to the state of resin; and when they are thickened to this point, they are no longer capable of fermenting, but secure from all putrefaction such bodies as are penetrated and well impregnated with them. On this is founded the theory of embalming.—The action of acids upon these oils, causes them to pass to the state of resin; and



there is no other difference between volatile oil and resin, than that which arises from this addition of oxigene.

All the oils, when they assume the character of resin by this combination of oxigene, let fall needle-formed crystals of camphor. Mr. Geoffroy has observed them in the oil of feverfew, marjoram, and turpentine. Acad. 1721, p. 163.

When the oil is changed by the combination of oxigene, it gradually loses its smell and volatility. To restore this oil to its original state, it is distilled. A thick matter remains in the distilling vessel, which consists of resin perfectly formed and is thus separated from the oil, which has not yet undergone the same alteration.

5. The habitudes of acids are not the same with all volatile oils. 1. The concentrated sulphuric acid thickens them: but, if it be diluted, it forms favonules. 2. The nitric acid, when concentrated, inflames them; but, when diluted, it causes them gradually to pass to the state of resin. Borrichius appears to have been the first who inflamed oil of turpentine with the sulphuric acid, without the nitric acid. Homberg repeated this delicate experiment with the other volatile oils. The inflammation of oils is so much the more easily effected, as the oil is more drying or greedy of oxigene, and the acid more easily decomposed. 3. The muriatic acid reduces oils to the saponaceous state, but the oxygenated muriatic acid thickens them.

3. Starkey appears to have been one of the first who attempted to combine a volatile oil with a fixed alkali. His process is long and complicated, like those of the alchemists; and the combination it afforded was known by the name of Starkey's Soap. the process of this chemist was so long merely because he used the carbonate of pot-ash, or mild vegetable alkali; but if ten parts of caustic alkali, or *lapis causticus*, be triturated hot with eight parts of oil of turpentine, the soap is instantaneously formed, and becomes very hard. This is the process of Mr. Geoffroy.—Acad. des Sciences, ann. 1725.

#### Concerning Camphor.

Camphor is obtained from a species of laurel which grows in China and Japan. Some travellers affirm that the old trees contain it so abundantly, that on splitting the trunk it is found in large tears, so pure as to have no need of rectifica-

tion. To extract the camphor, the roots of the trees are usually chosen; or, in want of these, all the other parts of the tree. These are put, together with water, into an iron alembic, which is covered with its head. The capital is fitted up internally with cords of rice straw, the joinings are luted, and the distillation proceeded upon. Part of the camphor sublimes, and attaches itself to the straw within the head; while another portion is carried into the receiver with the water. The Hollanders purify camphor by mixing an ounce of quick-lime with every pound of the substance, and subliming it in large glass vessels.

Camphor, thus purified, is a white concrete crystalline substance, of a strong smell and taste, soluble in alcohol, burning with a white flame, and leaving no residue: resembling volatile oils in many respects, but differing from them in certain properties; such as that of burning without certain properties; such as that of burning without a residue; of dissolving quietly, without decomposition or alteration, in acids; and of being volatilized by a gentle heat, without change of its nature.

Camphor is obtained by distillation from the roots of zedoary, thyme, rosemary, sage, the inula helenium, the anemomy, the pasque flower or pulsatilla, &c. And it is to be observed, that all these plants afford a much greater quantity of camphor when the sap has been suffered to pass to the concrete state, by a desiccation of several months. Thyme and pepper mint, slowly dried, afford much camphor; whereas the fresh plants afford volatile oil: most of the volatile oils, in passing to the state of resin, also let fall much camphor. Mr. Achard has likewise observed that a smell of camphor was disengaged when he treated the volatile oil of fennel with acids. The combination of the diluted nitric acid with the volatile oil of anise, afforded him a large quantity of crystals, which possessed most of the properties of camphor. He obtained a similar precipitate by pouring the vegetable alkali upon vinegar saturated with the volatile oil of angelica.

From all these facts it appears, that the base of camphor forms one of the constituent principles of some volatile oils; but it is in the liquid state, and does not become concrete but by combining with oxygen.

Camphor is capable of crystallization, according to Mr. Romieu, whether in sublimation, or when it is slowly precipitated from alcohol, or when alcohol is supersaturated with it; it precipitates in slender filaments, crystallizes in hexagonal blades attached to a common axis, and it sublimes in hexagonal pyramids or in polygonal crystals.

Camphor is not soluble in water; but it communicates its smell to that fluid, and burns on its surface. Romieu has observed that small pieces of camphor, of one-third or one-fourth of a line in diameter, being placed on the surface of pure water in a glass, have a rotatory motion: and this appears to be an electrical phenomenon; for the motion ceases if the water be touched with a conducting substance; but continues if it be touched with an insulating body, such as glass, sulphur, or resin. Bergen has observed that camphor does not turn upon hot water.

Acids dissolve camphor without producing any alteration in it, or becoming themselves decomposed: the nitric acid dissolves it quietly; and this solution has been called Oil of Camphor. Camphor precipitated from its solution in acids by the addition of alkalis, is heavier, harder, and much less combustible, according to the experiments of Mr. Kosegarten. By distilling the nitric acid several times from this substance, it acquires all the properties of an acid which crystallizes in parallelopipedons. To obtain the camphoric acid, nothing more is required than to distil the acid at several times from the camphor, and in a large quantity. Mr. Kosegarten distilled the nitric acid eight times from camphor, and obtained a salt crystallized in parallelopipedons, which reddened syrup of violets, and the tincture of turnsole. Its taste is bitter; and it differs from the oxalic acid in not precipitating lime from the muriatic acid.

With pot-ash it forms a salt which crystallizes in regular hexagons.

With soda it affords irregular crystals.

With ammoniac it forms crystalline masses, which exhibit crystals in needles and in prisms.

With magnesia it produces a white pulverulent salt, which may again be dissolved in water.



It dissolves copper, iron, bismuth, zinc, arsenic, and cobalt. The solution of iron affords a yellowish white powder, which is insoluble.

This acid forms, with manganese, crystals whose planes are parallel, and in some respects resemble basalt.

The camphoric acid, or rather the radical of this acid, exists in several vegetables; since camphor may be extracted from the oils of thyme, of cinnamon, of turpentine, of mint, of feverfew, of saffrafras, &c. Mr. Dehne has obtained it from the pasque flower, or pulsatilla; and Cartheuser has indicated several other plants which contain it.

Alcohol readily dissolves it, and it may be precipitated by water alone: this solution is known in pharmacy by the name of Camphorated Spirit of Wine, or Camphorated Brandy, when brandy is the solvent.

The fixed and volatile oils likewise dissolve each other by the assistance of heat; the solutions let fall crystals in vegetation, similar to those which are formed in the solutions of sal-ammoniac, composed of very fine filaments adhering to a middle part. This observation was made by Mr. Romieu. Acad. des Sciences, 1756.

Camphor is one of the best remedies which the art of medicine possesses. When applied to inflammatory tumours, it is resolvent; and, internally taken, it is antispasmodic, especially when dissolved in brandy. It is Given in Germany and in England in the dose of several drams per day; but in France our timid physicians do not prescribe it in a larger dose than a few grains. It mitigates heat in the urinary passage. It is given triturated with yolk of egg, sugar, &c.

It has likewise been supposed that its smell destroyed or drove away moths, and other insects which feed upon cloth, &c.

### ARTICLE III.

#### Concerning Resins.

The name of Resin is used to denote inflammable substances soluble in alcohol, usually affording much soot by their combustion; they are likewise soluble in oils, but not all in water.

All the resins appear to be nothing else but oils rendered concrete by their combination with oxigene. The exposure of these to the open air, and the decomposition of acids applied to them, evidently prove this conclusion.



Resins in general are less sweet than the balsams. They afford more volatile oil, but no acid, by distillation.

There are some among the known resins which are very pure, and perfectly soluble in alcohol, such as the balm of Mecca and of Copahu, turpentine, tacamahaca, elemi: others are less pure, and contain a small portion of extract, which renders them not totally soluble in alcohol; such are mastic, sandarach, guaiacum, laudanum, and dragon's blood.

1. The balsam of Mecca is a fluid juice which becomes thick and brown by age. It flows from incisions made in the amyris opobalsamum. It is known by the different names of Balm of Judea, of Egypt, of Grand Cairo, of Syria, of Constantinople, &c.

Its smell is strong, and inclining to that of lemons; its taste is bitter and aromatic.

This balsam, distilled by the heat of boiling water, affords much volatile oil.

It is balsamic; and is given incorporated with sugar, or mixed with the yolk of egg. It is aromatic, vulnerary, and healing.

2. The balsam of Copahu flows from a tree called Copaiba, in South America, near Tolu. It affords the same products, and possesses the same virtues, as the foregoing.

3. The turpentine of Chios flows from the turpentine tree, which affords the pistachios. It is fluid, and of a yellowish white colour inclining to blue.

This plant grows in Cyprus, at Chios, and is common in the south of France. The turpentine is obtained only from the trunk and large branches. Incisions are made first at the lower parts of the tree, and afterwards by degrees higher up.

This turpentine, distilled on the water-bath, without addition, affords a very white, very limpid, and very fragrant volatile oil: a more ponderous oil may be extracted at the heat of boiling water; and the residue, which is called Boiled Turpentine, affords by distillation, in the reverberatory furnace, a weak acid, a small quantity of brown consistent oil, and much coal.

The turpentine of Chios is very rare in commerce. Venice turpentine is extracted from the larix: its colour is a bright yellow, its consistence limpid, its smell strong and aromatic, and its taste bitter.

The tree which affords it is that which affords manna. Holes are bored during the summer near the bottom of the trunks of these trees, into which small gutters or tubes are inserted, to convey the juice into vessels intended to receive it. The resin is obtained only from trees in full vigour; the old trees very often have considerable depositions of resin in their trunks.

This turpentine affords the same principles as that of Chios.

It is used in medicine as a detergent for ulcers in the lungs, kidneys, &c. either incorporated with sugar, or mixed with the yolk of an egg, to render it more miscible with aqueous potions. The soap of Starkey, which we have spoken of under the article of Volatile Oils, is made with this turpentine.

The resin known in commerce by the name of Straßburgh Turpentine, is a resinous juice of the consistence of a fixed oil, of a yellowish white colour, a bitter taste, and a more agreeable smell than the preceding resins.

It flows from the yew-leaved fir, which is very common in the mountains of Switzerland. This resin is collected in blisters, which appear beneath the bark in the strong heats of summer. The peasants pierce these vesicles with the point of a small horn, which becomes filled with the juice, and is from time to time emptied into a larger vessel.

The balm of Canada differs from the turpentine of the fir in its smell only, which is more pleasant. It is obtained from a species of fir which grows in Canada.

Oil of turpentine is more particularly used in the arts. It is the great solvent for all resins; and, as it evaporates, it leaves them applied to the surface of bodies on which the mixture has been spread. As resins are the basis of all varnishes, alcohol and oil of turpentine must be the vehicles or solvents.

4. Pitch is a resinous juice, of a yellow colour, more or less inclining to brown. It is afforded by a fir named *Picea* or *Epicea*. Incisions are made through the bark; and the wound is renewed from time to time, as the lips become callous. A vigorous tree often affords forty pounds.

Pitch melted, and expressed through bags of cloth, is rendered purer. It is packed in barrels, by the name of White Pitch, or Burgundy Pitch.

White pitch mixed with lamp black, forms black pitch.

White pitch kept in fusion becomes dry. The desiccation may be facilitated with vinegar, and leaving it for a time over the fire. It then becomes very dry, and is called Colophony.

Lamp-black is the foot of burned pitch. It is likewise prepared by collecting the foot of pit-coal.

5. Galipot is a concrete resinous juice, of a yellowish white colour and strong smell. This juice comes from Guienne, where it is afforded by two species of pine, the *pinus maritima major*, et *minor*.

When these trees have acquired a certain size: a hole or notch is cut through the bark, near the bottom of the trunk. The resin issues out, and flows into vessels placed beneath to receive it. Care is taken to keep the wound open, and to renew it. The resin flows during the summer; but that which issues out during the spring, autumn, and winter, dries against the tree.

The pine likewise affords tar, and the oil called *huile de Cade*. For this purpose the wood of the trunk, branches, and roots, is heaped together and covered with turf, over which a fire is lighted, as if to convert them into charcoal. The oil which is disengaged, not being at liberty to escape, falls to the bottom into a channel or gutter, which conveys it into a tub. The most fluid part is sold under the name of *huile de Cade*; and the thicker part is the tar used for paying or painting the parts of shipping and other vessels.

The combination of several resins, coloured by cinnabar and minium, forms sealing-wax. To make the wax, take half an ounce of gum-lac, two drams of turpentine, the same quantity of colophony, one dram of cinnabar, and the same quantity of minium. The lac and the colophony, are to be first fused, after which the turpentine is to be added, and lastly the colouring matters.

6. Mastic has the form of white tears of a farinaceous appearance, having little smell, and a bitter astringent taste. Mastic flows naturally from the tree, but its produce is accelerated by incisions. The lesser turpentine tree, and the lentiscus, afford that which is met with in commerce.

Mastic affords no volatile oil when distilled with water. It is almost totally soluble in alcohol.



This resin is used in fumigations. It is chewed, to strengthen the gums; and it forms the basis of several drying varnishes.

7. Sandarach is a concrete resinous juice, in dry white transparent tears, of a bitter and astringent taste. It is obtained from most species of the juniper, and is found between the bark and the wood.

Sandarach is almost totally soluble in alcohol, with which it forms a very white varnish, that dries speedily. For this reason, the resin itself is known by us under the name of Varnish (*vernis*).

1. Labdanum is a black resinous juice, dry and friable, of a strong smell, and a disagreeable aromatic taste. It transudes from the leaves and branches of a kind of cistus, which grows in the island of Candia. Tournefort, in his Voyage to the Levant, informs us that when the air is dry, and the resin issues out of the pores of the cistus, the peasants strike all the parts of these trees with a kind of whip, made of several thongs of leather, fixed to the end of a staff. The juice adheres to the leather, and is cleared off with a knife. This is pure labdanum, and is very rare. That which is known by the name of *ladanum in tortis*, is mixed with a very fine ferruginous sand, for the purpose of increasing its weight.

9. Dragon's blood is a resin of a deep red in the mass, but brighter when in powder. It has neither taste nor smell.

It is obtained from the *drakena*, in the Canary islands, from which it flows in tears during the dog-days. It is also obtained from the ptero-carpus draco. The parts are exposed to the vapour of hot water; the juice issues out in drops, which are collected and wrapped up in the leaves of reeds.

The dragon's blood of the shops, which has the form of flattened orbicular loaves, is a composition of various gums, to which this form is given, after they have been coloured with a small quantity of dragon's blood.

Dragon's blood is soluble in alcohol: the solution is red: the resin itself may be precipitated of the same colour.

This resin is used in medicine as an astringent.

#### ARTICLE IV.

##### Concerning Balsams.

Some authors define balsams to be fluid inflammable substances; but there are some which are dry. Others again



give this name to the most fragrant among the resins. M. Bucquet has confined this denomination to such resins only as have a sweet flavour, capable of being communicated to water; and which more especially contain fragrant acid and concrete salts, which may be separated by decoction or sublimation. It appears therefore that these substances contain a principle not found in resins, which combining with oxygen, forms an acid; while the oil, saturated with the same air, forms the resin. This acid salt is soluble in water and alcohol. As the chemical analysis points out a sufficiently striking difference between balsams and resins, we think it proper to treat them separately.

The substances called Balsams are therefore resins united with a concrete acid salt. We are acquainted with three principal kinds; viz. benzoin, the balsam of Tolu, and the storax calamita.

1. Benzoin is a coagulated juice, of a pleasant fragrant smell, which becomes stronger by friction and heat.

Two varieties of this substance are known; the benzoë amygdaloides, and the common benzoin. The first is composed of the most beautiful tears of this balsam, connected together by a gluten of the same nature, but browner, and of the aspect of nutmegs in its fracture. The second is merely the juice itself, without any mixture of these fine and very pure tears. It comes to us from the kingdom of Siam, and the island of Sumatra; but we do not know the tree that affords it\*.

Benzoin, laid upon hot coals, fuses, speedily takes fire, and emits a strong aromatic smell. But if it be merely heated, without setting it on fire, it swells up, and emits a more pleasant though less powerful smell.

Benzoin pounded, and boiled in water, affords an acid salt, which crystallizes in long needles by cooling. This salt may also be extracted by sublimation. It rises by a degree of heat even less than that which is required to raise the oil of benzoin; and this is the substance called Flowers of Benzoin, or the Sublimed acid of Benzoin. Neither of the seprocesses are economical; and in the preparation of these articles, in the large way, I begin by distilling the benzoin, and cause all the

\* For a drawing and description of this tree, consult Dryander, in the Phil. Trans. vol. lxxvii. No. 31.

products to pass confounded together into a capacious receiver. I then boil the product in water, and by this means I obtain a much greater quantity of the salt of benzoin: because, in this state, the water attacks and dissolves the whole contents; whereas the most accurate trituration will not produce the same effect.

The sublimed acid of benzoin has a very penetrating aromatic smell, which excites coughing; more especially if the subliming vessels be opened while yet hot. It reddens the syrup of violets, and effervesces with the alkaline carbonates. It unites with earths, alkalis, and metals, and forms benzoates, of which Bergmann and Scheele have given us some account.

Alcohol dissolves benzoin totally, without leaving any residue but such foreign impurities as the balsam may happen to contain. It may be precipitated by the addition of water; and then constitutes the opake fluid called *Lac Virginal*.

Benzoin is used as an aromatic in medicine: but it is seldom used in substance, because of its sparing solubility: its tincture, and volatile acid, are used. The latter is a good in isive medicine to be administered in pituitous obstructions of the lungs, the kidneys, &c. It is given in extracts, or dissolved in water.

Benzoin is employed in fumigations for indolent tumours. The oil is likewise an excellent resolvent. It is applied by friction to members affected with cold rheumatic and paralytic disorders.

2. The balsam of Tolu, of Peru, or of Carthagera, has a mild and pleasant smell.

It is met with in commerce in two different forms; either in shells, or in the fluid state. The coco is softened by boiling water, and the balsam flows out in the fluid form.

The tree which affords it, is the *Toluisera* of Linnæus. It grows in South America, in the district called Tolu, between Carthagera and Nombre de Dios.

The fluid balsam affords much volatile oil when distilled by the heat of boiling water.

An acid salt may be extracted from this balsam, which greatly resembles that of benzoin, and may be obtained by the same processes; but this sublimed salt is commonly

brown, because it is soiled by a portion of the balsam, which rises with a less heat than benzoin does.

This balsam is soluble in alcohol, and may be precipitated by the addition of water.

It is much used in medicine, as an aromatic, vulnerary, and antiputrescent remedy. It is administered either triturated with sugar, or mixed with some extract. A syrup is prepared from it by digesting it in a gentle heat with sugar; or by dissolving it in alcohol, adding sugar, and suffering the alcohol to dissipate spontaneously.

It is falsified by macerating the distilled oil of benzoin upon the buds of the balsm-scented poplar, and adding a small quantity of the natural balsam.

Storax or styra calamita is a juice of a very strong but pleasant smell. Two varieties are known in commerce: the one in reddish clean tears; the other in masses of a blackish red colour, soft and fatty.

The plant which affords it is called the oriental liquid amber. It has been long supposed to be the *styrax folio mali cotonæi* C. B. which is known in Provence, in the wood of La Chatreusé de Montrieu, by the name of Alibousier; and, according to Duhamel, affords a very odorant juice, which he took for storax.

Its habitudes during analysis are the same as the preceding, and it exhibits the same phenomena.

It was formerly brought to us in canes or reeds, whence its name of storax calamita.

These three balsams form the base of those fragrant pastils which are burned in the chambers of the sick, to conceal or disguise bad smells. These balsams are made into masses by means of gum; with the addition of charcoal and the nitrate of pot-ash, to facilitate combustion.

## ARTICLE V.

### Concerning Gum Resins.

The gum resins are a natural mixture of extract and resin. They seldom flow naturally from plants, but issue out from incisions made for that purpose. They are sometimes white, as in the tithymalus and the fig-tree; sometimes yellow, as in the chelidonium: so that we may consider these substances

as true emulsions, whose constituent principles vary in their proportions.

The gum resins are partly soluble in water, and partly in al. ohol.

One character of gum resins is, that they render water turbid in which they are boiled.

This class is sufficiently numerous: but we shall only treat of the principle species, and more especially those which are used in medicine.

1. *Olibanum*, or frankincense, is a gum resin, in tears of a yellowish white colour and transparent. Two kinds are known in trade: the male incense, in small very pure tears; and the female incense, in large and impure tears.

The tree which affords it is not known. Some authors suppose it to be the cedar with cypress leaves.

*Olibanum* contains three parts of resinous matter, and one of extract. When it is boiled in water, the solution is white and turbid, like that of all the juices of this class. When it is fresh, it affords a quantity of volatile oil.

*Olibanum* is used in medicine as a resolvent. But its chief use is in our temples, where it has been adopted as one of the instruments of worship of the Divinity.

It is used in hospitals, to disguise the smell of the putrid air which is exhaled. M. Achard has proved that this proceeding has no other effect than that of deceiving the sense of smelling.

2. *Scammony* is of a blackish grey colour, a bitter and acrid taste, and a strong nauseous smell.

Two varieties are met with in commerce; one of which comes from Aleppo, and the other from Smyrna. The first is paler, lighter, and more pure; the second is black, heavy, and mixed with foreign substances.

It is extracted from the *convolvulus scammonia*, principally from the root. For this purpose incisions are made at the head of the root: it is collected in muscle shells. But most of that met with in trade is obtained from the roots by expression.

From the results of the analysis of Geoffroy and Cartheuser, it appears that the proportion of the component parts varies in the different specimens examined. The latter



obtained near one half of extract, whereas the former only one sixth.

Scammony is used in medicine as a purgative, in the dose of several grains. When triturated with sugar and almonds, it forms a very agreeable purgative emulsion. When softened by a mixture of the juice of liquorice, or of wild quinces, it forms the diagredium.

3. Gum guttæ has a reddish yellow colour: it has no smell, but its taste is acrid and caustic. Gum guttæ was brought to Clusius in 1630. It comes from the kingdom of Siam, from China, and from the island of Ceylon, in cylinders of various sizes. The tree which affords it is called Coddam Pull. Herman reports, from his own observation as an eye witness, that a milky and yellowish juice flows from incisions made in these trees; that this juice becomes thick by the heat of the sun; and that, when it is a state fit to be handled, it is formed into large globular masses.

Geoffroy has extracted five sixths of resin from gum guttæ. Cartheuser has ascribed to it more extractive than resinous matter.

Gum guttæ is sometimes used as a purgative, in a dose of a few grains. But the principle use of this substance is in painting, where it is recommended by the beauty of its colour.

4. *Affa fœtida* is met with in tears of a yellowish white colour; but most commonly in the form of loaves formed by the aggregation of a number of the tears. It has an acrid and bitter taste, and its smell is one of the most disagreeable.

The plant which affords it is called *Ferula Affa Fœtida*.

This plant grows in Persia: and the juice of its root is obtained by expression, according to Kæmpfer. It is fluid and white when it issues from the plant, and it emits an abominable smell when recent. This juice loses its smell, and becomes coloured, as it dries. But it still preserves smell enough to entitle it to the name of *Stercus Diaboli*.

The Indians find its flavour agreeable; they use it for seasoning, and call it the *food of the gods*: a proof which evinces, beyond every argument, that tastes must not be disputed.

Cartheuser found it to contain one third of resin.

It is a solvent and discutient remedy; and more particularly valuable as a most powerful antihysterical.

5. Aloes is a juice of a red brown colour, and very considerable bitterness. Three species are distinguished—the soccotrine aloes, the hepatic aloes, and the coballine aloes; they differ only in their degree of purity. M. de Jussieu, who saw these three varieties prepared at Morviedro in Spain, assures us that they are all obtained from the aloë vulgaris. The first variety is obtained by making incisions in the leaves. Time is allowed for its impurities to subside perfectly. The fluid is then decanted from the dregs, and left to become thick; after which it is put into leathern sacks for sale, under the name of Soccotrine aloes. A juice of the same nature is obtained by expression from the same leaves, which, when clarified in the same manner, forms the hepatic aloes: and the coballine aloes is obtained by a stronger pressure.

The Soccotrine aloes contains no more than one eighth of resin, according to Boulduc. The hepatic aloes contains half its weight.

Aloes is very much used in medicine as a purgative, tonic, alterative, and vermifuge.

6. Gum ammoniac is sometimes met with in small tears, white within, and yellow without. But they are often united in the mass, resembling the benzoë amygdaloides.

Its smell is fetid; and its taste acrid, bitter, and rather nauseous.

This juice comes from the deserts of Africa, and the plant which affords it is unknown: it is presumed to be of the class of umbelliferous plants, from the figure of the seeds found in it.

Gum ammoniac is very much used in medicine. It is a very good alterative; and is given in pills, incorporated with sugar, or in some extract. It may even be dissolved or diffused in water; this liquid becomes turbid, and of a yellowish white. Gum ammoniac enters into the composition of all discutient plasters.

#### Concerning Caoutchouc, or Elastic Gum.

Elastic gum is one of those substances which it is difficult to class. It burns like resins; but its softness, its elasticity,

and its insolubility in the menstrooms which usually dissolve resins, do not allow us to class it among those bodies.

The tree which affords it is known by the name of Seringa by the Indians of Para. The inhabitants of the province of Esmeraldas, a province of Quito, call it Hhava; and those of the province of Mainas, Caoutchouc.

Mr. Richard has proved that this tree is of the family of the euphorbia; and Mr. Dorthes has observed, that the *coccus* which are covered with a down that resembles small straws, were covered with a gum very much resembling the elastic gum. These insects feed on the euphorbium; but those which come from other situations afford the same juice.

We are indebted to Mr. Condamine for an account, and accurate details, concerning this tree. (Acad. des Sciences, 1751.) This academician informs us, after M. Fresneau, engineer at Cayenne, that the caoutchouc is a very lofty tree. Incisions are made in the bark; and the white juice, which flows out in a more or less liquid state, is received in a vessel placed for that purpose. This is applied in successive coatings upon a mould of clay, and dried by the fire, or in the sun. All sorts of designs are traced upon it while soft; and, when it is dry, the clay mould is crushed, and the pieces shaken out.

This gum is very elastic, and capable of great extension.

When elastic gum is exposed to the fire, it becomes soft, swells up, and burns with a white flame. It is used for illumination, instead of candles, at Cayenne.

It is not at all soluble either in water or alcohol. But Macquer has assured us that ether is its true solvent; and upon this property he has instituted the art of making bougies for chirurgical uses of elastic gum, by applying this solution upon a mould of wax till it is of the requisite thickness.

Mr. Berniard, to whom we are indebted for important observations upon this substance, found only the nitric ether to dissolve elastic gum. Very pure sulphuric ether did not perceptibly act upon it.

If elastic gum be put in contact with a volatile oil, such as that of turpentine, or even if it be exposed to the vapour of that fluid, it swells, softens, and becomes very pasty. It may then be spread upon paper, or applied as a varnish to cloth; but this covering preserves its adhesive

quality, and does not lose it for a long time. The mixture of volatile oil and alcohol forms a better solvent than the pure oil, and the varnish dries more speedily.

Mr. Berniard has concluded from his experiments that the elastic gum is a fat oil, coloured by a matter soluble in alcohol, and soiled by the smoke to which the gum is exposed in drying.

If linseed oil be rendered very drying by digesting it upon the oxides of lead, and it be afterwards applied with a small brush upon any surface, and dried by the sun or in the smoke, it affords a pellicle of a considerable degree of firmness, evidently transparent, burning like the elastic gum, and wonderfully elastic and extensible. If this very drying oil be left in a wide shallow vessel, the surface becomes thick, and forms a membrane which has the greatest analogy with the elastic gum. A pound of this oil spread upon a stone, and exposed to the air for six or seven months, acquired almost all the properties of elastic gum. It was used to make catheters and bougies; was applied to varnish balloons, &c.

Some gum resins are cleared by art of their extractive principle, for the purpose of applying them to various uses. Such is the intention of the process used to make bird-lime. This is made from different substances, as the berries of mistletoe, the fruit of the sebestien, &c. But the best is made of the hollyoak. These trees are peeled in the month of June or July: the outer bark is rejected, and the second is boiled in spring water for seven or eight hours. It is then made into masses, which are buried in the ground, and covered with stones, for several layers one over the other. After having previously drained off the moisture, they are suffered to ferment for fifteen days, until the matter has acquired the adhesive consistence of paste. The mass is then beaten till it becomes capable of being wrought with the hands, or kneaded; after which it is washed in a running stream. Lastly, it is placed for three or four days in another vessel, that it may throw up its skum or impurities; in which last state it is put into proper vessels, and kept for use.

The following composition is likewise made use of under the name of bird-lime. Take one pound of bird-lime, one pound of goose-grease; add to this one ounce of vinegar,



half an ounce of oil, and the same quantity of turpentine. Boil the mixture for several minutes, and heat the mass when you are desirous of using it as a cement. It may be prevented from freezing in winter, by adding a small quantity of petroleum.

#### Concerning Varnish.

The Pere d'Incarville has informed us that the tree which affords the varnish of China is called Tsi-chou by the Chinese. This tree is propagated by off-sets. When the cultivator is desirous of planting this, he takes a branch, which he wraps up in a mass of earth, by means of flax. Care is taken to moisten this earth; the branch pushes out roots, and is then pruned and transplanted. This tree grows to the size of a man's leg.

This varnish is drawn in spring. If it be a cultivated tree, it affords three gatherings. It is extracted by incisions made in the spring; and when the varnish, which is received in shells, does not flow, several hogs bristles, moistened with water or spittle, are introduced into the wound, and cause it to run. When the tree is exhausted, the upper part of it is wrapped in straw, which is set on fire, and causes the varnish to precipitate to the bottom of the tree, where it flows out of perforations made for that purpose.

Those who collect the varnish set out before day-break, and place their shells beneath the apertures. The shells are not left longer than three hours in their place, because the heat of the sun would evaporate the varnish.

The varnish emits a smell which the workmen are very careful to avoid respiring. It produces an effect which they call the bud of the varnish.

When the varnish issues from the tree, it resembles pitch. By exposure to the air it naturally becomes coloured, and is at last of a beautiful black.

The juice which flows from incisions made in the trunk and branches of the thus toxicodendron, possesses the same properties. The tree that grows in our climates affords a white milky fluid, which becomes black and thick by the contact of the air; its colour is the most beautiful black: and it would be easy to introduce this valuable species of

industry into the kingdom, because the tree grows wonderfully well in all climates, and resists the cold of the winter.

To make the varnish bright, it is evaporated by the sun; and a body is given to it with hog's gall, and the sulphate of iron, or martial vitriol.

The Chinese use the oil of tea, which they render drying by boiling it with orpiment, realgar, and arsenic.

The varnishes most used in the arts have all of them the resins for their base; and the fundamental facts in this valuable art are reducible to the following principles.

To varnish any substance, consists in applying upon its surface a covering of such a nature, as shall defend it from the influence of the air, and give it a shining appearance.

A coat of varnish ought therefore to possess the following properties:—1. It must exclude the action of air; because wood and metals are varnished to defend them from decay and rust. 2. It must resist water; for otherwise the effect of the varnish could not be permanent. 3. It ought not to alter such colours as are intended to be preserved by this means.

It is necessary therefore that a varnish should be easily extended or spread over the surface, without leaving pores or cavities; that it should not crack or scale; and that it should resist water. Now resins are the only bodies that possess these properties.

Resins consequently must be used as the bases of varnish. The question which of course presents itself must then be, how to dispose them for this use; and for this purpose they must be dissolved, as minutely divided as possible, and combined in such a manner that the imperfections of those which might be disposed to scale, may be corrected by others.

Resins may be dissolved by three agents—1. By fixed oil. 2. By volatile oil. 3. By alcohol. And accordingly we have three kinds of varnish: the fat or oily varnish, essential varnish, and spirit varnish.

Before a resin is dissolved in a fixed oil, it is necessary to render the oil drying. For this purpose the oil is boiled with metallic oxides; in which operation the mucilage of the oil combines with the metal, while the oil itself unites with the oxigene of the oxide. To accelerate the drying of this varnish, it is necessary to add oil of turpentine.

The essential varnishes consist of a solution of resin in oil of turpentine. The varnish being applied, the essential oil flies off, and leaves the resin. This is used only for paintings.

When resins are dissolved in alcohol, the varnish dries very speedily, and is subject to crack; but this fault is corrected by adding a small quantity of turpentine to the mixture, which renders it brighter, and less brittle when dry.

The coloured resins or gums, such as gum guttæ, dragon's blood, &c. are used to colour varnishes.

To give lustre to the varnish after it is laid on, it is rubbed with pounded pumice stone and water; which being dried with a cloth, the work is afterwards rubbed with an oiled rag and tripoli. The surface is last of all cleaned with soft linen cloths, cleared of all greasiness with powder of starch, and rubbed bright with the palm of the hand.

## ARTICLE VI.

### Concerning the Fecula of Vegetables.

The fecula appears to be only a slight alteration of mucilage; for it differs from that substance in no other respect than in being insoluble in cold water, in which liquid it falls with wonderful quickness. If it be put into hot water, it forms a mucilage, and resumes all its characters. It seems that the fecula is simply a mucilage deprived of caloric. In fact, a young plant is all mucilage; the old plants and fruits afford little fecula, because the heat is stronger in young than in old plants, according to Dr. Hunter.

There are few plants which do not contain fecula. Mr. Parmentier has given us a list of all those which afford it, in his experiments. (See his *Recherches sur les Vegetaux Nourissans*.) But the seeds of gramineous and leguminous vegetables, as well as the roots, which botanists call *Tuberoses*, contain it most plentifully.

Nothing more is required, in order to extract the fecula, than to bruise or grind the plant in water; and the fecula, which is at first suspended in that fluid, soon falls to the bottom. We shall not in this place attend to any other feculæ but such as are used in the arts or in medicine. Such are those of bryony, of potatoes, cassava, sago, salep, starch, &c.

1. The fecula of bryony is extracted from the root of

that plant. The bark is first taken off from the root, which is then rasped, and submitted to the press. The juice which flows out by expression is rendered white and opake by a fecula which subsides. The liquid is then decanted off, and the fecula dried. It is strongly purgative, on account of a portion of extract which it retains; but it may be deprived of its purgative virtue by careful washing in water. If water be poured on the marc which remains beneath the press, a large quantity is obtained which is not purgative, because the extractive matter was forced out by the first operation. Mr. Baumé has proposed to substitute this fecula instead of starch. The fecula is afforded by similar treatment of the roots of corn-flag and arum.

2. That which is generally known by the name of *Potatoe Flour*, is nothing but the fecula of this root obtained by ordinary and easy processes. The root being well washed, it is pounded or crushed in such a manner as perfectly to destroy its texture. The pulp is then put into a sieve, and water poured on it, which carries off the fecula, and deposits it at the bottom of the receiving vessel. The water, which is coloured by extractive matter, and part of the parenchyma that remains suspended, is decanted off, and the deposition is washed several times. The colour of the fecula grows whiter as it dries; and when dry it is very white and fine.

As this fecula has become an article of common use for some time past, several instruments have been contrived which are more or less suited to bruise the potatoes. Rasps have been proposed turning in cylinders, mills armed with points of iron, &c.

3. The cassava of the Americans is extracted from the roots of the manioc. This plant contains an acrid and very dangerous poison, of which it must be very carefully deprived. The Americans take the fresh root of manioc, which they peel, rasp, and inclose in a bag or sack formed of rushes, and of a very open texture. This bag is suspended from a staff; and a very heavy vessel is fastened to its lower part, which draws the bag down, so as in some measure to compress the root, at the same time that it receives the juice as it flows out. The juice is a most dreadful poison. When the root is well cleared of the juice, it is put into the same bags, and exposed to dry in the smoke. The sifted root is



called Cassava. To convert it into food, it is spread out upon an hot brick or plate of iron; and when the surface which rests immediately on the brick is of a reddish brown colour, it is turned, to bake the other side; and in this state it forms what is called Cassava Bread.

The expressed juice carries with it the finest part of the fecula, which quickly subsides; and this fecula, known by the name of Mouchasse, is used to make pastry.

The poisonous extract which most of these roots that abound in fecula contain, ought to engage those who prepare them to be uncommonly attentive to the due management of the process. Without the most scrupulous care the most unhappy consequences may follow. It should always be recollected, in the preparation of these substances, that the poison is in contact with the food.

A fecula has likewise been appropriated to domestic uses which is extracted from the pith of several farinaceous palms, and is known by the name of Sago. This preparation is made in the Molucca Islands. The pith of middle-aged palms is only used; for the young, as well as the old, affords very little fecula. This pith is mixed with water; and the fecula which is extracted, and renders the fluid white, is suffered to subside. When the fecula is dried, it forms small grains; which when reduced to powder, and mixed with warm water, affords a very nourishing pulp or mucilage.

M. Parmentier has proposed to make sago out of potatoes; in consequence of his idea that all feculæ are absolutely identical, and that this principle is one and the same in nature. For this purpose he proposes to add a spoonful of the fecula of potatoes gradually to a chopin, or half a pint, of hot water or milk, to be kept stirring over a gentle fire for half an hour. Sugar may be added, with aromatics or spices, such as cinnamon, lemon peel, saffron, orange-flower water, rose-water, &c.

The sago of potatoes may likewise be prepared with veal broth, chicken broth, or common broth. The preparation may be varied in a thousand ways, and it forms a very wholesome and nourishing food.

5. The bulbs of all the kinds of orchis may be used to make salep. All that is required to be done consists in

depriving them of the extractive principle, and drying the residue, which becomes transparent by this operation.

In order to dry them more speedily, they are strung, and hung up; or otherwise it is thought sufficient to rub these bulbs in water either hot or cold, and to dry them in an oven. This last process was communicated to Dr. Percival by Mr. John Moulton.

The fecula of salep, pulverized, and combined with water, forms a very nourishing jelly.

6. The fecula is likewise one of the constituent principles of the seeds of gramineous plants; and when these have been ground, and reduced into farina, nothing more is required than to mix them with water, in order to precipitate the fecula. But another process for procuring it is used in the arts: it consists in destroying by fermentation the extractive and glutinous part, with which it is intimately united; and in this consists the art of making starch. The process of the starch-maker consists in fermenting grain, pollard, damaged flour, &c. in the acid water which they call *eau sure*. When the fermentation is ended, they take out the fecula, which is precipitated to the bottom of the water, and put it into hair sacks. Fresh water is poured upon this, which carries the finer fecula with it; and this being several times washed, constitutes starch, cleared of every foreign principle.

There are likewise coloured feculæ, such as indigo, which we shall treat of when we come to the article Dying.

The uses of feculæ are very numerous.

1. They constitute a very nourishing food, because the nutritive virtue of gramineous vegetables resides in them. Those seeds which man has appropriated for his food, contain much; and these feculæ form a very nourishing jelly with hot water. It may be seen, in the work of Mr. Parmentier, that this is truly the most suitable nourishment for man. Some of these are even entirely devoted to this purpose, such as the cassava.

In the northern climates, the lichens form almost the whole of the food of man, and such animals as are not carnivorous: and these lichens, according to the experiments of the Academy of Stockholm, afford an excellent starch by simple grinding. The rein-deer, the stags, and the other fallow cattle of the north of Europe, subsist on the lichen rangi-

ferinus. The Icelanders obtain a very delicate gruel with fecula of the lichen *Icelandicus*.

2. Starch boiled in water, and coloured with a small quantity of azure, forms a paste which is used to give brightness, firmness, strength, and an agreeable colour, to linen.

3. The feculæ are also used to make hair powder; and this consumption, which is prodigious, might be supplied by starch made from less valuable plants than the gramineous; and, if this were done, the objects of luxury would not enter into competition with our most immediate wants.

## ARTICLE VII.

### Concerning the Vegetable Gluten.

The glutinous principle, which, on account of its properties resembling those of animal substances, has been called the *Vegeto-Animal Substance* by some chemists, is more particularly obtained from gramineous vegetables. We are indebted to Beccari for the discovery of this substance; and the analysis of farinaceous substances has since been enriched with various important facts.

To make the analysis of any farina, the methods employed are such as are simple, and incapable of decomposing or altering any of its constituent parts. A paste is formed with the flour and water; and this is kneaded and wrought in the hands under water, till it no longer communicates any colour to that fluid. The substance which then remains in the hand is tenacious, ductile, and very elastic; and becomes more and more adhesive, in proportion as the water which it had imbibed flies off by evaporation. In this same operation the fecula falls to the bottom of the water; while the extractive matter remains in solution, and may be concentrated by evaporation of the fluid.

If the glutinous matter be stretched out, and then let go, it returns by spontaneous contraction to its original form. If it be left suspended, it becomes extended by its weight; and forms a very thin transparent membrane, which exhibits a kind of net work, resembling the texture of the membranes of animals.

M. Beccari has observed that the proportion of glutinous matter varies prodigiously in the several seeds of gramineous vegetables. Those of wheat contain the largest quantity;

but he never found it in the garden stuff or plants which are used by us for food. The quantity of glutinous matter also varies in the same kind of grain, according to the nature of the soil which has supported it. Humid situations afford scarcely any.

The glutinous matter emits a very characteristic animal smell. Its taste is insipid; it swells up upon hot coals; becomes soon and perfectly dry in a dry air, or by a gentle heat; in which state it resembles glue, and breaks short like that substance. If in this state it be placed on burning coals, it curls up, is agitated, and burns like an animal substance. By distillation it affords the carbonate of ammoniac.

Fresh-made gluten, exposed to the air, readily putrifies; and when it has retained a small quantity of starch, this last passes to the acid fermentation, and retards the putrefaction of the gluten: and in this way a state is produced resembling that of cheese.

Water does not attack the glutinous part. If it be boiled with this fluid, it loses its extensibility and adhesive quality: a circumstance so much the more remarkable, as it was indebted to that fluid for the development of these qualities; for this principle existed without cohesion in the flour; and when it is deprived of water by drying, it also loses its elasticity and glutinous quality.

Alkalis dissolve it, by the assistance of a boiling heat. The solution is turbid; and deposits the gluten by the addition of acids, but deprived of its elasticity.

The nitric acid dissolves gluten with activity; and this acid at first emits the nitrogenous gas, as when treated with animal substances. This is followed by an emission of nitrous gas; and the residue, by evaporation, affords the oxalic acid in crystals.

The Sulphuric and muriatic acids likewise dissolve it. M. Poulletier has observed, that salts with base of ammoniac may be obtained from these combinations dissolved in water or alcohol, and evaporated in the open air.

If the gluten be dissolved in the vegetable acids several times repeatedly, and precipitated by alkalis, it is restored to the state of fecula: and according to Macquer, if vinegar be distilled by a gentle heat from this substance, it is reduced to the state of mucilage.



This substance therefore possesses a very decided animal character. It is to this gluten that wheat owes its property of making a good paste with water, and the facility with which it rises. Rouelle discovered a glutinous substance analogous to the present in the green fecula of plants, which afford ammoniac, and empyreumatic oil, by distillation. The expressed juice of the herbaceous plants likewise afforded it; such as that of borage, hemlock, sorrel, &c.

The gluten is sometimes destroyed by the fermentation of flour; by which change it is deprived of the wholesome qualities it before possessed, and is incapable of rising, and forming good bread.

Farina, or flour, is therefore composed of three principles—the amylaceous principle, or starch; the saccharine principle; and the animal or glutinous principle. Whenever therefore, by a suitable division, these principles are mixed together, and the fermentation is assisted by the known methods, each of these principles being capable of a different kind of fermentation, becomes disposed in its own peculiar manner. The saccharine principle undergoes the spirituous fermentation; the glutinous suffers the process of animal putrefaction; and the amylaceous is changed by the acid fermentation. The panary fermentation may therefore be considered as an union of these three different spontaneous changes. But as soon as the leading phenomena of the fermentation are well developed; and the principles, already well mixed and assimilated, have by this means suffered a change of their respective natures; the fermentation is stopped by baking: and the bread is found to be much lighter in consequence of these preliminary operations.

The art of making bread was not known at Rome until the year 585. The Roman armies, on their return from Macedonia; brought Grecian bakers into Italy. Before this time the Romans prepared their flour in no other way than by making it into pap or soft pudding; for which reason the Romans, according to Pliny, were called Eaters of Pap\*. See Aubery.

\* Pulvis autem, non panis, vixisse longo tempore Romanos manifestum, quoniam inde et Pulmentaria hodieque dicuntur. Plin. Hist. Nat. lib. xviii. cap. viii. et xi.—The date is 580 ab urbe condita. T.

## ARTICLE VIII.

## Concerning Sugar.

Sugar is likewise a constituent part of vegetables, existing in considerable quantities in a number of plants. It is afforded by the maple, the birch, wheat, and turkey corn. Margraff obtained it from the roots of beet, red beet, skirret, parsnips, and dried grapes. The process of this chemist consisted in digesting these roots, rasped or finely divided, in alcohol. This fluid dissolves the sugar; and leaves the extractive matter untouched, which falls to the bottom.

In Canada the inhabitants extract sugar from the maple (*acer montanum candidum*). At the commencement of spring they heap snow in the evening at the foot of the tree, in which they previously make apertures for the passage of the returning sap. Two hundred pounds of this juice afford by evaporation fifteen of a brownish sugar. The quantity prepared annually amounts to fifteen thousand weight.

The Indians likewise extract sugar from the pith of the bamboo.

But the sugar which is so universally used is afforded by the sugar cane (*arundo saccharifera*) which is raised in our colonies. When this plant is ripe, it is cut down, and crushed by passing it between iron cylinders, placed perpendicularly, and moved by water or animal strength. The juice which flows out by this strong pressure is received in a shallow trough placed beneath the cylinder. This juice is called *vesou*; and the cane, after having undergone this pressure, is called *begasse*\*. The juice is more or less saccharine, according to the nature of the soil on which the cane has grown, and the weather that has predominated during its growth. It is aqueous when the soil or the weather has been humid; and in contrary circumstances it is thick and glutinous.

The juice of the cane is conveyed into boilers, where it is boiled with wood ashes and lime. It is subjected to the same operation in three several boilers, care being taken to remove the skum as it rises. In this state it is called Syrup;

\* These are the names in the French sugar colonies. I do not find the corresponding terms in any of our writers. T.

and is again boiled with lime and alum till it is sufficiently concentrated, when it is poured into a vessel called the Cooler. In this vessel it is agitated with wooden stirrers, which break the crust as it forms on the surface. It is afterwards poured into casks, to accelerate its cooling; and, while it is still warm, it is conveyed into barrels standing upright over a cistern, and pierced through their bottom with several holes stopped with cane. The syrup which is not condensed filters through these canes into the cistern beneath; and leaves the sugar in the state called Coarse Sugar, or Muscovado. This sugar is yellow and fat, and is purified in the islands in the following manner:—The syrup is boiled, and poured into conical earthen vessels, having a small perforation at the apex, which is kept closed. Each cone, reversed on its apex, is supported in another earthen vessel. The syrup is stirred together, and then left to crystallize. At the end of fifteen or sixteen hours, the hole in the point of each cone is opened, that the impure syrup may run out. The base of these sugar loaves is then taken out, and white pulverized sugar substituted in its stead; which being well pressed down, the whole is covered with clay, moistened with water. This water filters through the mass, carrying the syrup with it which was mixed with the sugar, but which by this management flows into a pot substituted in the place of the first. This second fluid is called Fine Syrup. Care is taken to moisten and keep the clay to a proper degree of softness, as it becomes dry. The sugar loaves are afterwards taken out, and dried in a stove for eight or ten days; after which they are pulverized, packed and exported to Europe, where they are still farther purified.

The operation of our sugar refiners consists in dissolving cassonade, or clayed sugar, in lime water. Bullocks blood is added, to promote the clarifying; and when the liquor begins to boil, the heat is diminished, and the skum carefully taken off. It is in the next place concentrated by a brisk heat; and, as it boils up, a small quantity of butter is thrown in, to moderate its agitation. When the boiling is sufficiently effected, the fire is put out; the liquor is poured into moulds, and agitated, to mix the syrup together with the grain sugar already formed. When the whole is cold,

the moulds are opened, the loaves are covered with moistened clay, which is renewed from time to time till the sugar is well cleared from its syrup. The loaves being then taken out of the moulds, are carried to a stove, where they are gradually heated to the fiftieth degree of Reaumur. They remain in this stove eight days, after which they are wrapped in blue paper for sale.

The several syrups, treated by the same methods, afford sugars of inferior qualities; and the last portion, which no longer affords any crystals, is sold by the name of Melasses. The Spaniards use this melasses in the preparation of sweetmeats.

A solution of sugar, much less concentrated than that we have just been speaking of, lets fall by repose crystals which affect the form of tetrahedral prisms, terminated by dihedral summits, and known by the name of Sugar Candy.

Sugar is very soluble in water; it swells up in the fire, becomes black, and emits a peculiar smell, known by the denomination of the smell of caromel.

Sugar is very much used for domestic purposes. It constitutes the basis of syrups; and is used at our tables to disguise the sour taste of fruit and vegetable juices. It corrects the bitterness of coffee; and serves as the vehicle in a great number of pharmaceutical preparations.

Sugar is an excellent food; and it is merely an old prejudice to suppose it produces worms in the bowels of children.

It is now several years since the celebrated Bergmann taught us to extract a peculiar acid from sugar, by combining the oxigene of the nitric acid with one of its constituent principles. The discovery of the acid of sugar was consigned in a thesis maintained at Upsal, the 13th of June 1776, by M. Arvidson, under the presidency of Bergmann.

To make the acid of sugar, or oxalic acid, nine parts of the nitric acid, with one of sugar, are put into a retort. A gentle heat is applied, to assist the action of the acid; which is rapidly decomposed upon the sugar, with the disengagement of a considerable quantity of nitrous gas. When the decomposition is completed, the distillation is continued on a sand bath, till the residue is sufficiently concentrated. It is then suffered to cool; and beautiful crystals are formed, which may be taken out, and have the figure of a tetra-



hedral prism terminating in a dihedral summit. By a farther concentration of the liquor in which the acid has crystallized, more of these crystals may be obtained. These several products of crystals are then to be dissolved in pure water, and again crystallized, to separate them from any admixture of nitric acid that may adhere to them. This acid was formerly thought to be a modification of the nitric acid; and Bergmann was under the necessity of entering into a considerable detail of reasoning, to remove every doubt on the subject. But the knowledge we at present possess respecting the constituent principles of the nitric acid, and the great number of phenomena of this kind which it exhibits when made to act on various substances, render it unnecessary for us to enter into this consideration.

Cold water dissolves half its weight of this acid, and boiling water takes up its own weight.

This acid, combined with pot-ash, forms a salt in prismatic hexahedral flattened rhomboidal crystals, terminating in dihedral summits. In order that crystallization may take place, it is necessary that one of the component parts should be in excess. This salt is very soluble in water.

The same acid forms with soda a salt which is very difficult to be brought to crystallize, and which converts syrup of violets to a green.

This acid, poured upon ammoniac, affords by a slight evaporation very beautiful tetrahedral prismatic crystals, terminating in dihedral summits; one of whose faces is larger than the other, so that it occupies three angles of the extremity. See my *Memoirs of Chemistry*.—This salt is of great use in the analysis of mineral waters. It instantly shews the presence of any salt with basis of lime, because the oxalate of lime is insoluble in water.

The acid of sugar, or oxalic acid, attacks and dissolves most of the metals: but its action upon the oxides is stronger than upon the metals themselves; and it takes the oxides from their true solvents. In this way it is that it precipitates the iron from a solution of the sulphate of iron, in a substance of the most beautiful yellow colour, which may be used in painting.

It precipitates copper in the form of a white powder, which becomes of a beautiful light green by drying.

Zinc is precipitated of a white colour.

This acid likewise precipitates mercury and silver, but not till after several hours standing.

An account of the combinations of this acid with various bases may be seen in Bergmann's treatise.

This acid may be extracted, by the action of nitric acid, from a number of vegetable substances, such as gums, honey, starch, gluten, or alcohol; and from several animal substances, according to the discovery of M. Berthollet, such as silk, wool, and lymph.

M. de Morveau, who has made a very valuable series of experiments on the acid of sugar, has proved that the whole of the sugar does not enter into the formation of the acid, but only one of its principles; and he affirms that it is an attenuated oil which exists in a variety of substances.

Since it has been ascertained, from the experiments of Scheele, Westrumb, Hermitadt, and others, that the acid of the salt of sorrel does not at all differ from that of sugar, they have been accordingly confounded under the same denomination; and that salt which is known in commerce by the name of Salt of Sorrel, is an acidulous oxalate of pot-ash.

The salt of sorrel is made in Switzerland, in the Hartz, in the forests of Thuringia, in Swabia, and elsewhere. It is extracted from the juice of the sorrel called Alleluja. Juncker, Boerhaave, Margraff, and others, have described the process used for its extraction. The juice of sorrel is expressed, diluted with water, filtered, and evaporated to the consistence of cream. It is then covered with oil, to prevent its fermentation, and left in a cellar for six months.

According to M. Savary, fifty pounds of this plant afford five and twenty of juice, from which no more than two ounces and a half of the salt are obtained. Six parts of boiling water dissolve one of the salt. It appears to crystallize in parallelopipedons, according to De Lisle.

Margraff observed that the nitric acid, digested upon salt of sorrel, afforded nitre.

Calcareous earth has the property of disengaging the alkali; and in this operation the carbonic acid of the chalk unites with the alkali of the salt and forms a carbonate of pot-ash.

Salt of sorrel unites with other bases without yielding its own; so that the results are triple salts. See the *Encyclopédie Methodique*, tom. i. p. 200, 201.

The pure oxalic acid may be obtained by distillation of this salt, as Mr. Savary informs us; or otherwise by depriving it of its alkali by means of sulphuric acid, and distillation, according to Wieglieb's method: or otherwise by the process of Scheele, which consists in saturating the excess of acid with ammoniac, and pouring the nitrate of barytes into the solution. The nitric acid then seizes the two alkalis, while the oxalic acid unites with the barytes, and falls down. The barytes is afterwards taken from its combination by the sulphuric acid, and leaves the oxalic acid disengaged.

Scheele has likewise proposed another method of obtaining the pure oxalic acid. It consists in dissolving the salt in water, and pouring in a solution of salt of saturn. A precipitate is formed; and the supernatant liquor contains the alkali of the salt of sorrel, united with a portion of the vinegar. The precipitate is then washed, and sulphuric acid poured on, which unites with the lead: and, by filtering and evaporating, the oxalic acid is obtained in crystals, similar to those of the acid of sugar.

Scheele has proved the identity of the acid of salt of sorrel with that which is extracted from sugar. He dissolved the acid of sugar to saturation in cold water, and into this he very gradually poured a well-saturated solution of pot-ash. During the effervescence, he observed that small transparent crystals were formed, which were found to be a true salt of sorrel.

Mr. Hoffman has proved that the juice and the crystals of the *berberis vulgaris* contain the oxalic acid combined with pot-ash. And the celebrated Scheele has proved that the earth of rhubarb is a combination of the oxalic acid with lime.

#### ARTICLE IX.

##### Concerning the Vegetable Acids.

The vegetable acids have been long considered to be weaker than the others; and this opinion was adhered to until it was observed that the oxalic acid seized lime from the sulphuric acid. The principal character which may serve to establish a line of distinction between the vegetable acids and others are—1. Their volatility; for there are none which do not rise with a moderate heat. 2. Their property

of leaving a coaly residue after combustion, and of emitting an empyreumatic smell in burning. 3. The nature of their acidifiable base, which is in general oily.

But are all the vegetable acids identical in their nature? And may they not be considered as modifications of one and the same acids?

If we depend on the principle laid down by the celebrated *Monro*, who considers no acids as identical but such as form exactly the same salts with the same base (*Phil. Trans.* vol. lvii. p. 479), there will be no question but that all the known acids ought to be considered as very different from each other. But this method of proceeding appears to me to be erroneous; because in this case the various degrees of saturation of the same principle with oxygen, would establish various kinds of acids. The slow or the rapid combustion of phosphorus causes sufficient modifications in the acid to afford different phosphoric salts, according to the Experiments of *Messrs. Sage and Lavoisier*. But ought we on this account to admit of two species of phosphoric acid? By following the method of *Monro*, which is that of most chemists, we might multiply the vegetable acids to infinity; but by collating the experiments of *Hermstadt, Crell, Scheele, Westrumb, Berthollet, Lavoisier, &c.* we may observe that the vegetable acids are merely modifications of one or two primitive acids.

1. *Scheele* obtained vinegar by treating sugar and gum with manganese and the nitric acid. He observed that tartar had the same effect or habitude as sugar in the solution of manganese by the nitric acids; and that vinegar was found after the decomposition of ether.

2. *Mr. Crell*, by boiling the residue of nitric alcohol (dulcified spirit of nitre) with much nitric acid, taking care to adapt vessels to condense the vapour, and saturating what came over with alkali, obtained nitrate and the acetate of pot-ash. The latter being separated by alcohol, gives out its vinegar by the usual treatment.

3. The same chemist, by boiling the pure oxalic acid with twelve or fourteen parts of nitric acid, observed that the former disappears; and the receiver is found to contain nitrous acid, acetous acid, carbonic acid, and nitro-



genous gas; and in the retort there remains a little calcareous earth\*.

4. By saturating the residue of nitric alcohol with chalk, an insoluble salt is obtained; which, treated with the sulphuric acid affords a true tartareous acid.

5. By boiling one part of oxalic acid with one part and a half of manganese, and a sufficient quantity of nitric acid, the manganese is almost totally dissolved, and vinegar with nitrous acid pass into the receiver.

6. By boiling tartareous acid and manganese with the sulphuric acid, the manganese is dissolved, and vinegar with sulphuric acid are obtained.

7. By digesting for several months the tartareous acid and alcohol, the whole becomes changed into vinegar; and the air of the vessels is found to consist of carbonic acid and nitrogene gas.

From these facts Crell concludes that the tartareous, oxalic, and acetous acids, are merely modifications of the same acid.

In the *Journal de Physique* for September 1787, is inserted a memoir of M. Hermstadt on the conversion of the oxalic and tartareous acids into acetous acid.

1. By causing the oxygenated muriatic acid to pass through very pure alcohol, ether is produced; and the oxygenated acid resumes its character of ordinary muriatic acid. The ether by distillation affords—1. Ether. 2. Muriatic alcohol. 3. Vinegar mixed with regenerated muriatic acid.

2. Nitric acid distilled, for several successive times, from the oxalic and tartareous acids, converts them totally into acetous acid.

3. Two parts of oxalic acid, three of sulphuric acid, and four of manganese, mixed with one part and a half of water, and distilled together, afford acetous acid, which requires to be rectified and redistilled to become very pure.

4. If the sulphuric acid be boiled upon the oxalic or the tartareous acid, these two last are not destroyed, as Bergmann thought, but they are converted into acetous acid.

\* There being an obvious oversight in the author's paragraph, I have taken the liberty to restore the passage from Crell's original. *Journal de Phys.* Oct. 1785, quoted by Dr. Beddoes at the end of the English Translation of Scheele's Essays. London, 1789. T.

It is proved, by the experiments of M. Hermstadt, that the sulphureous acid in the receiver, when ether is made, is mixed with much acetous acid.

It appears therefore to be proved that the tartareous, oxalic, and acetous acids differ from each other only in the proportion of oxigene.—In the above experiments the mineral acids are always decomposed; and, by saturating the radical with their oxigene, they constantly form the acetous acid. If the saturation be not exact, the result is either oxalic or tartareous acid; which is still more proved by a fine experiment of M. Hermstadt. If three parts of fuming nitric acid be put into the pneumatic apparatus, and a large jar be adapted, filled with water; if then one part of good alcohol be poured in, by a little at a time, the mixture will be heated every time a drop of the alcohol is let fall, and a great quantity of bubbles will rise into the receiver. When the operation is ended, if care be taken to collect the gas, it will be found to consist of nitrous gas, a small quantity of carbonic acid, and about a twelfth part of the acetous air of Priestley. The residue affords oxalic acid and acetous acid. The oxalic acid disappears if the operation be continued; ether is formed; and the acetous acid remains, and becomes more in quantity.

Mr. Hermstadt has likewise succeeded in converting the acids of tamarinds, of citrons, of marc of grapes, the juice of plums, apples, pears, gooseberries, berberries, sorrel, and others, into the oxalic, tartareous, and acetous acids.

From all these experiments it appears, that the oxigene, combined with a principle of alcohol, forms the oxalic acid; and that a more accurate saturation of this principle with oxigene forms the tartareous and acetous acids.

M. Lavoisier has proved that the known vegetable acids do not differ from each other but in the proportion of hydrogen and carbone, and in their degree of oxygenation.

I have proved (in the Memoirs of the Academy of Sciences of Paris for the year 1786) that water impregnated with the gas disengaged from the juice of grapes in fermentation, passes the state of acetous acid.

It appears that the vegetable acids may be considered in two very different points of view. Most of them exist in the

plant itself; but the properties and acid characters are disguised by their combination with other principles, such as oils, earths, alkalis, &c. On the other hand, several acids are extracted from vegetables, which did not exist in nature. In this case the plant contained only the radical, and the reagent with which it is treated affords the oxygen.

The mere distillation of most vegetables is sufficient to develop an acid, which was disguised by oily, alkaline, or earthy substances.

1. The peculiar acid called the Pyro-mucilaginous acid, is afforded by distillation by all plants which contain a saccharine juice.

For the preparation of this acid, the quantity of sugar intended to be operated upon is put into a very capacious retort (the large size being requisite, because the matter swells up), and a receiver sufficiently ample to condense the vapour is adapted. An astonishing quantity of carbonic acid and hydrogen gas are disengaged by the first impression of the fire. A brown fluid remains in the receiver, most of which consists of a weak acid, colouring blue paper, and rendered dark by a portion of oil. The retort contains a spongy coal. M. Schrickel advises the rectification of the product of the first distillation from clay, in order to purify the acid: but M. de Morveau has redistilled it without intermedium; and the acid he obtained had only a slight yellow tinge. Its specific gravity was 1,0115, the thermometer standing at twenty degrees.

As this acid rises at the same temperature as water, it is not possible to concentrate it by distillation. But this purpose may be effected by freezing; and in this manner it was that M. Schrickel prepared the acid he made use of to ascertain its combinations.

This acid exists in all bodies capable of passing to the spirituous fermentation, while they contain only the radical of the oxalic acid. The pyromucilaginous acid is combined in the vegetable with oils in the saponaceous state.

This concentrated acid has a very penetrating taste. It strongly reddens blue colours. If it be exposed to heat in open vessels, it is dissipated, and leaves only a brown spot. If it be heated in closed vessels, it leaves a more considerable residue, of the nature of the coal of sugar.

This acid speedily attacks the earthy and alkaline carbonates, and forms salts differing from the oxalates. According to Mr. Schrickel, it dissolves gold. He affirms that he made the experiment in the presence of Fred. Aug. Cartheuser. Lemery had asserted that the spirit of honey possessed this property; and this opinion is likewise supported in the works of Depré, Etmüller, &c. Neumann opposed the assertion; and the experiments of M. de Morveau confirm those of this last chemist.

Silver is not attacked by the pyromucilaginous acid; but mercury combines with it by virtue of a long digestion. Consult De Morveau.

This acid corrodes lead, and forms a very styptic salt in long crystals. With copper it forms a green solution. It partly dissolves tin, and affords green crystals with iron.

2. The denomination of the Pyroligneous Acid has been given to the acid obtained by distillation from wood. It has been long known that the hardest woods afford an acid principle, mixed with an oil, which partly disguises its properties; but no one had directly attended to a determination of the habitudes of this acid, till M. Goettling published, in Crell's Annals for 1779, a series of researches on the acid of wood, and the ether it affords.

M. de Morveau, to obtain this acid, distilled small pieces of very dry beech in an iron retort, by a reverberatory furnace. He changes the receiver when the oil begins to rise, and rectifies his product by a second distillation. Fifty-five ounces of very dry chips afforded seventeen ounces of rectified acid, of an amber colour, not at all empyreumatic; whose specific gravity, compared with that of distilled water, was as 49 : 48.

This acid strongly reddens blue vegetable colours. One ounce required twenty-three ounces and a half of lime water for its complete saturation.

It supports the action of heat very well when it is engaged in an alkaline base; but by a strong heat it is burned, like all the vegetable acids.

It does not precipitate martial solutions of a black colour.

It unites with alkalis, earths, and metals. It does not give up lime or barytes to combine with caustic alkalis.



The action of the pyroligneous acid upon metallic substances, and upon alumine, may be compared with that of the acetous acid, and appears to follow the same order.

This acid dissolves near twice its weight of the oxide of lead.

3. The citric acid. Lemon juice is in a disengaged state in the fruit, and exhibits its acid properties without any preparation. This acid is nevertheless always mixed with a mucilaginous principle, capable of altering by fermentation. Mr. Georgius has described, in the *Memoirs of Stockholm* for the year 1774, a method of purifying this acid without changing its properties. He fills a bottle with lemon juice, closes it with a cork, and preserves it in a cellar. The acid was preserved for four years, without corrupting. The mucilaginous parts had fallen down in flocks; and a solid crust was formed beneath the cork, the acid itself having become as limpid as water. To dephlegmate the acid, he exposes it to frost; and observes that the temperature ought not to be too cold, because in that case the whole would become solid; and though the acid would thaw the first, it would always be productive of some inconvenience. In order to concentrate it to better advantage, the ice must be separated as it forms. The first ice is tasteless, and the last is rather sour; and by this means the liquor is reduced to half. The acid thus concentrated is eight times as strong, two gros only being required to saturate one gros of pot-ash.

The citric acid, when thus purified and concentrated, may be kept for several years in a bottle; and serves for all uses, not excepting that of making lemonade.

The chemists in general who have examined the combinations of the citric acid, have used it in its original state, embarrassed with its mucilaginous principle. Such is the result of the experiments of M. Wenzel, who obtained only gummy products. But M. de Morveau having saturated the purified acid with crystals of pot-ash, found a non-deliquescent salt at the end of a certain time.

The combinations of this acid are little known.

4. The malic acid.—This acid was announced by Scheele in 1785, and published in *Crell's Annals*. In order to obtain it, the juice of apples is saturated with alkali, and the acetous solution of lead is poured in until it occasions no more pre-

precipitate. The precipitate is thenedulcorated, and sulphuric acid poured on it until the liquor has acquired a fresh acid taste, without any mixture of sweetness. The whole is then filtered, to separate the sulphate of lead. This acid is very pure, always in the fluid state, and cannot be rendered concrete.

It unites with the three alkalis, and forms deliquescent neutral salts. When saturated with lime, it affords small irregular crystals, which are soluble only in boiling water. Its habitude with barytes is the same as with lime.

With alumine it forms a neutral salt of sparing solubility in water, and with magnesia a deliquescent salt.

It differs from the citric acid—1. Because the citric acid saturated with lime, and precipitated by the sulphuric acid, crystallizes; whereas this is not crystallizable. 2. The malic acid, treated with the nitric acid, affords the oxalic acid; the citric does not afford it. 3. The citrate of lime is almost insoluble in boiling water; the malate of lime is more soluble. 4. The malic acid precipitates the solutions of the nitrates of lead, of mercury, and of silver; but the citric acid produces no change. 5. If the solutions of the nitrate of ammoniac, and malate of lime, be boiled together for an instant, the latter salt is decomposed, and nitrate of lime falls down; which proves that the affinity of the malic acid with lime is weaker than that of the nitric.

The celebrated Scheele, who has rendered us acquainted with this acid, has published the following table of the fruits which afford this acid, either pure or mixed with other acids.

The expressed juices of the fruits of

Berberis vulgaris, the barberry tree,	} Afford much malic acid, and little or none of the citric acid.
Sambucus nigra, Elder,	
Prunus spinosa, Sloe,	
Sorbus aucuparia, Service,	
Prunus domestica, Ca. den plum,	
Ribes grossularia, the Hairy Gooseberry,	} Appear to contain half of the one and half of the other.
Ribes rubrum, the Currant,	
Vaccinium myrtillus, Whortleberry,	
Cratægus aria, Common Lotus,	
Prunus Cerasus, Cherry,	
Fragaria vesca, Strawberry,	
Rubus chamaemorus, Bilberry,	}
Rubus idæus, Raspberry,	

*Vaccinium oxycacos*, Marshwhortle,  
*Vaccinium Vitis Idæa*,  
*Prunus padus*, Bird's Cherry,  
*Solanum dulcamara*,  
*Clynosbatus*, Eglantine,  
*Citrus*, Citron or Lemon,

} Contains much citric, and little or none of the malic acid.

According to the same chemist, the juice of green grapes, as well as that of tamarinds, contains only the acid of citrons.

Scheele has likewise proved the existence of the malic acid in sugar. If weak nitric acid be poured on sugar, and distilled till the mixture begins to turn brown, all the oxalic acid may be precipitated by the addition of lime-water; and another acid will remain, which the lime-water does not precipitate. To obtain this acid in a state of purity, the liquor is saturated by means of chalk, then filtered, and alcohol added, which occasions a coagulation. This coagulation, well washed in alcohol, is redissolved in distilled water. The malate of lime is decomposed by the acetate of lead; and, last of all, the malic acid is disengaged by the sulphuric acid. The alcohol by evaporation leaves a substance rather bitter than sweet, which is deliquescent, and resembles the saponaceous matter of lemon juice. If a small quantity of nitric acid be distilled from this, the malic and oxalic acids are obtained.

By treating various other substances with the nitric acid, the malic and oxalic acids are likewise obtained. Such are gum arabic, manna, sugar of milk, gum adragant, starch, and the fecula of potatoes. The extract of nut-galls, the oil of parsley seed, the aqueous extract of aloes, of coloquintida, of rhubarb, of opium, afforded not only the two acids to Mr. Scheele, but likewise much resin.

This celebrated chemist, by treating several animal substances with very concentrated nitric acid, obtained the malic and the oxalic acids from them. Fish glue, or isinglass, white of egg, yolk of egg, and blood, treated in the same manner, afforded the same products.

There are few vegetables which do not exhibit some acid more or less developed. We see, for example, all fruits, insipid at first, become insensibly acid; and finish by losing that taste, and become saccharine. There are some which constantly preserve an acid taste, and form a particular class.

Some plants contain an acid principle diffused through the whole parenchyma or body of the vegetable. Such are the yellow gilly-flower, bardana or waterdock, filipendula or dropwort, water cresses, the herb robert, &c. These plants sensibly redden blue paper.

There are others in which the acid principle exists only in part of the plant; as, for example, in the leaves of the greater valerian, the fruit of the winter cherry and of the cornel tree, the bark of burdock, and the root of aristolochia or birthwort.

Mr. Monro communicated some experiments to the Royal Society of London, in 1767, which prove that certain vegetables contain acids nearly in a disengaged state, and even such as are the least promising on a slight examination.

1. Having peeled two dozen of summer apples, and cut them into small pieces, he poured water upon them, in which he had previously dissolved two ounces of soda, and left the whole to stand for six days. The filtrated liquor, evaporated, and left in repose for six days more, afforded a beautiful salt, in small round transparent plates, placed edgewise on each other.

2. The juice of mulberries clarified with the white of egg, and saturated with soda, afforded a pulverulent salt of no regular figure; which by repeated solutions and evaporations, at last produced long crystals, one kind being thin, and the other thicker, which crossed each other.

3. He obtained small cubical or rhomboidal crystals by treating peaches and oranges with soda.

4. The green plum afforded, after several solutions and crystallizations, a neutral salt, which crystallized without evaporation in large hexagonal plates, and partly in large rhombi. This salt had a hot taste, and was soluble in three or four times its weight of cold water.

5. The red gooseberry afforded, by evaporation and cooling, small very hard rhomboidal crystals, not changeable in the air; whose taste resembled that of the salt produced by a combination of the citric acid with the same base.

The green gooseberry produced a saline crust formed of small rhomboidal crystals, and covered with their brilliant scales.



6. The green grape afforded Mr. Munro, by repeated solutions, a neutral salt, in small cubical crystals, of a rhomboidal or parallelogramic figure, lying upon and intersecting each other.

The juice of hemlock afforded M. Baumé a salt in small irregular crystals, nearly tasteless, but reddening the infusion of turnsole.

6. M. Rinman, in his History of Iron, places the forbapple and floe among the substances capable of corroding and cleansing the surface of this metal, on account of their acid.

When, by the decomposition of certain vegetables by the nitric acid, an acid was obtained as the last result, it was thought to have existed ready formed in the vegetable; but a more intimate examination shewed that the acid made use of in this operation was merely decomposed, while it destroyed the organization of the vegetable, disunited the combinations which retained the principles, and that the oxygenous base of this acid, by uniting with an element of the vegetable, formed a particular acid. This truth is deduced from the combined processes of M. Lavoisier, De Morveau, &c.

It is to a similar cause that we ought to attribute the formation of the acetous, the carbonic, and other vegetable acids; and even the rancidity of oils, and the alteration to which some other principles of the vegetable kingdom are subject. In these cases the air affords the oxygen which becomes fixed in the plant, and gives it an acid nature.

The oxalic acid does not exist ready formed in sugar, neither is the camphoric acid ready formed in camphor. The same may be observed of several other acids which are extracted by means of certain acids decomposed by being treated with vegetable substances. We shall speak of these acids when we come to treat of their radical principles.

## ARTICLE X.

### Concerning Alkalis.

Alkali exists ready formed in plants. Duhamel and Grosse have proved that it might be extracted by means of acids. Margraff and Rouelle have added new proofs in support of the assertions of these chemists. They have observed, from their experiments, that the alkali existed in a disengaged

state in vegetables : but these experiments proved at most that their state of combination is such that it may be broken by the mineral acids. The alkali, in some instances, is nearly in a disengaged state; for it is found in combination with carbonic acid in the *helianthus annuus*. But the alkali of plants is often combined with the oily principle.

When it is required to extract the alkali from a vegetable substance, all the principles with which it may be united, are destroyed by fire; and it is cleared from the residues of the combustion by lixiviation. This is the process used to make the impure alkali, called *salin*, as we have already observed.

If wood remains a long time under water, it is deprived of its property of affording an alkali by combustion; because the water dissolves the compounds which may contain it.

Marine plants afford an alkali of another nature, known by the name of Soda. Vegetables possess the power of decomposing common sea salt, and retaining its alkaline base. All insipid plants are capable of affording more or less of soda if they be raised on the sea coast; but they perish there in a short time.

Ammoniac is likewise found in plants. The glutinous part of gramineous vegetables contain it, and give it out to the nitric, muriatic, and other acids, according to M. Poulletier : and nothing more is required than to triturate the essential salt of wormwood with fixed alkali, to separate the volatile. This alkali appears to be one of the principles of the tetradynamia, as these afford it by simple distillation.

Alkalis likewise exist in plants in the state of neutral salts. They are combined with the sulphuric acid in old borage and in some astringent plants. The sulphate of pot-ash appears to exist in almost all vegetables, as the pot-ash contains more or less of it; and the analysis of tobacco has afforded me a considerable quantity.

Tamarisc affords the sulphate of soda in such abundance, that by extracting it from the ashes of this plant, it can be afforded in very beautiful and pure crystals at thirty livres the quintal.

The greater turnsole, *parietaria*, and borage contain nitrate of pot-ash.

The muriates of soda and of pot-ash are afforded by marine plants.

We likewise find the alkalis combined with the acids of vegetation, such as the oxalic, the tartareous, and other acids.

It appears that the several salts are the products of the vegetation, and peculiar effect of the organization, of vegetables. Two plants which grow in the same soil, afford very different salts; and each plant constantly affords the same kind. Besides this, Homberg observed (*Mem. Acad. Par.* 1669) that the same salts were developed by plants growing in earths previously well washed, and afterwards watered with distilled water.

We may therefore class salts among the principles of vegetables, and no longer consider them as accidentally contained in plants. I do not however deny that the combustion of a plant may not give rise to some of them, and increase or diminish the proportions of others. Combustion must form combinations which did not exist in the plant, and destroy several of those which existed before. The atmospheric air employed in this operation must unite with certain principles, and produce various results. The nitro-gene gas which is precipitated in torrents in the focus of combustion, probably combines with some of the principles to form alkalis, and consequently may augment the quantity of those which naturally exist in the plant.

#### ARTICLE XI.

##### Concerning the Colouring Principles.

The object of the art of dying consists in depriving one body of its colouring principle, to fix it upon another in a durable manner; and the series of manipulations necessary to produce this effect, constitutes the art itself. This art is one of the most useful and wonderful of any we are acquainted with; and if there be any one of the arts which is capable of inspiring a noble pride, it is this. It not only affords the means of imitating nature in the riches and brilliancy of her colours; but it appears to have surpassed her in giving a greater degree of brilliancy, fixity, and solidity to the fugacious and transient colours with which she has clothed the productions around us.



The series of operations which constitute the art of dying, are absolutely dependant on the principles of chemistry: and though it is to accidents, or the very slight combination of facts suggested by the comparison of a few circumstances, that we are indebted in this part of chemistry for several excellent receipts, and some principles; yet it is not the less true, that no considerable progress will ever be made, nor any solid foundation established, but by analysing the operations, and reducing them to general principles, which chemistry alone can afford. The necessity of establishing proper principles is still farther evinced by the uncertainty and continual trials which prevail in the manufactories. The slightest change in the nature of the substances puts the artist to a stand, inasmuch that he is incapable of himself of remedying the defects which arise. Whence follow continual losses, and a discouraging alternation of success and disappointment.

The little progress which chemistry has hitherto made in the art of dying, depends on several causes, which we shall proceed to explain.

The first cause of this slow progress depends on the difficulty of ascertaining with any degree of certainty the nature, properties, and affinities, of the colouring principle. In order to extract this principle, we must be acquainted with the nature of its solvent; we must know whether the principle be in a state of purity, or mixed with other parts of the vegetable; whether this colouring matter consist of one principle alone, or is formed by the union of a number: we must also render ourselves acquainted with its affinities with various kinds of stuff; for it is ascertained by experience that certain colours adhere very well to wool, though they do not alter the whiteness of cotton. In addition to these necessary parts of knowledge, it will likewise be required to determine its affinity with the mordant, for alum is the mordant for some colours and not others: besides which, the action or effect of other bodies upon the colour when dyed must be ascertained, in order to contrive the means of defending it from alteration, &c.

The second cause which has retarded the application of chemistry to dying, is the difficulty the chemist finds in procuring opportunities of making experiments in the large way.



Prejudice, which reigns despotically in the dye-house, tends to expel the chemist as a dangerous innovator; and the proverb, that *Experience is better than Science*, contributes to prevent the introduction of improvements into manufactories. It is very certain that a dyer, confined to the mere practical part of his business, will without controversy produce a better scarlet than a chemist who is acquainted only with the principles; for the same reason as a simple workman in clock making will make a better watch than the most celebrated mechanic. In these cases we may admit that experience is better than science; but when it is required to resolve any problem, to explain any phenomenon, or to discover some error in the complicated details of an operation, the mere artizan is at the end of his knowledge, is totally at a loss, and would derive the greatest advantage from the assistance of the man of science.

Another cause of the slow progress of chemistry in the art of dying, is, that most of the works which treat upon this art are confined to descriptions of the processes used in the manufactories. These works, it must be admitted, possess their advantages; but they do not advance the science of operations a single step. They only exhibit the sketch of a country, without indicating either its relative situation, or the nature of its products. It has indeed been very difficult, till lately, to do more than this; because the gases, which are so greatly concerned in this part of chemistry, were unknown; because the action of light and of the air, which is so powerful upon colours, was a fact of which neither the cause nor the theory could be known; and more particularly because the salts and combinations of three, four and five principles were not known, though they very much tend to render the effects of operations on vegetables more complicated.

In order therefore to make a progress in the art of dying, we must ground our reasoning on other principles. I shall proceed to sketch out a plan which seems to me to be adapted to this purpose. We shall examine—

1. The manner in which the colours of various bodies are developed and formed.
2. The nature of the combinations of these same colours in these bodies, and the properest means of extracting them.

3. The most advantageous processes for applying them.

1. Colours are all formed in the solar light. The property which bodies possess of absorbing some rays, and reflecting others, forms the various tinges of colours with which they are decorated, as is proved from the experiments of Newton.

From this principle we may consider the art of dying under two very different points of view. For we may determine the colour upon a body either by changing the form and disposition of its pores; so that it may acquire the property of reflecting a different kind of rays from those which it reflected before it was subjected to these mechanical operations. Thus it is that by trituration we change the colour of many bodies; and to this cause it is that we must refer all the effects dependant on the reflexibility and refrangibility of rays. This coloration depends, as we see, merely on the changes produced in the surfaces of bodies, or the disposition of their pores. The phenomena of refrangibility depend on the density or specific gravity of bodies, according to Newton and Delaval.

The other method of causing a body to exhibit a determinate colour, consists in transferring to the surface of the body some other body or substance which possesses the property of reflecting this known ray. This is the effect chiefly produced by dying.

But in what manner do the coloured bodies of the three kingdoms of nature acquire the property of constantly reflecting one determinate kind of rays? This is a very delicate question; for the elucidation of which I shall bring together a few facts.

It appears that the three colours which are the most eminently primitive in the arts; those which form all the others by their combination, and consequently the only colours to which we need pay attention; that is to say, the blue, the yellow, and the red—are developed in the bodies of the three kingdoms by a greater or less absorption of oxigene, which combines with the various principles of those bodies.

In the mineral kingdom, the first impression of fire, or the first degree of calcination, developes a blue colour, sometimes interspersed with yellow, as is observable when lead, tin, copper, iron, or other metals, are exposed in a state

of fusion to the action of the air, to hasten their cooling. This may be especially observed in steel plates which are coloured blue by heating.

Metals acquire the property of reflecting the yellow colour by combining with a greater quantity of oxigene; and accordingly we perceive this colour in most of them, in proportion as the calcination advances. Massicot, litharge, ochre, orpiment, and yellow precipitate, are instances of this.

A stronger combination of oxigene appears to produce the red; whence we obtain minium, colcothar, red precipitate, &c.

This process is not uniform through all the bodies of the mineral kingdom; for it is natural to infer that the effects must be modified by the nature of the base with which the oxigene combines. Thus it is that in some of them we perceive the blue colour almost immediately followed by a black; as may easily be accounted for, on the consideration that there is a very slight difference between the property of reflecting the weakest rays and that of reflecting none at all.

To give additional force to the observations here made, we may also take notice that the metals themselves are most of them colourless, and become coloured by calcination; that is to say, by the fixation and combination of oxigene.

The effects of the combination of oxigene are equally evident in the mineral as in the vegetable kingdom; and, in order to convince ourselves of this, we need only follow the operations in the method of preparing and developing the principal blue colours, such as indigo, pastel, turnsole, &c.

Indigo is extracted from a plant known by the name of Anillo by the Spaniards, and the Indigo Plant by us. It is the *Indigofera tinctoria* of *Linnaeus*. It is cultivated at Saint Domingo, in the Antilles, and in the East Indies. The boughs are cut every two months, and the root lasts two years. The plant is laid to ferment in a trough called the steeping trough, which is filled with water. At the end of a certain time the water heats, emits bubbles, and becomes of a blue colour. It is then passed into another vessel or trough, called the beating trough (batterie), where the fluid is strongly beaten or agitated by a mill with pallets, to condense the substance of the indigo. As soon as the water is



become insipid, it is drawn off; and the deposition of the fecula is made in a third vessel, called the settling trough (repositoir), where it dries, and is taken out to form the loaves distributed in commerce.

The pastel is a colour which is extracted in Upper Languedoc, by fermenting the leaves of the plant after having first bruised them. The fermentation is promoted by moistening them with the most putrid water that can be procured.

The woad is prepared in Normandy in the same manner as the pastel.

Turnsole is prepared at Grand Galargues by soaking rags in the juice of the croton tinctorium, and afterwards exposing them to the vapour of urine or dung.

We likewise observe that the first degree of combination of oxigene with oil (in combustion) develops the blue colour for the instant.

The blue colour is formed in dead vegetables only by fermentation. Now in these cases there is a fixation of oxigene. This oxigene combines with the fecula in indigo, with an extractive principle in turnsole, &c.; and most colours are likewise susceptible of being converted into red by a greater quantity of oxigene. Thus it is that turnsole reddens by exposure to air, or to the action of acids: because the acid is decomposed upon the mucilage, which is the receptacle of the colour; as may be seen in syrup of violets, upon which the acids are decomposed when concentrated. The same thing does not happen when a fecula is saturated with oxigene, and does not admit of the decomposition of the acid. Hence it is that indigo does not become red by acids, but is on the contrary soluble in them. It is likewise for the same reason that we observe a red colour developed in vegetables in which an acid continually acts, as in the leaves of the oxalis, of the virgin vine, the common sorrel, and the ordinary vine. Hence also it happens that acids brighten most of the red colours; and that a very highly charged metallic oxide is used as the mordant for scarlet.

We find the same colours developed in the animal kingdom by the combination of the same principle. When flesh-meat putrefies, the first impression of the oxigene consists in producing a blue colour; whence the blue appearance of mortifications, of flesh becoming putrid, of game too long



kept, or the appearance which in our kitchens in France is called *cordon bleu*. This blue colour is succeeded by red, as is observed in the preparation of cheeses, which become covered with a mouldiness at first of a blue colour, but afterwards becoming red : I have pursued these phenomena in the preparation of cheeses at Rocquefort. The combination of oxigene, and the proportional quantity which enters into such combination, determine therefore the property of reflecting any particular rays of light. But it may easily be understood that the colour must be subject to variation, according to the nature of the principle with which it combines ; and this points out a series of very interesting experiments that remain to be made.

All the phenomena of the combination of air with the several principles in different proportions, may be observed in the flame of bodies actually on fire. This flame is blue when the combustion is slow ; red, when stronger and more complete ; and white, when still more perfect. For these final degrees of oxidation in general produce a white colour, because all the rays are then equally reflected.

From the foregoing facts we may conclude that the blue ray is the weakest, and is consequently reflected by the first combination of oxigene. We may add the following fact to those we have already exhibited. The colour of the atmosphere is blueish : the light of the stars is blue, as M. Mariotte has proved, in the year 1678, by receiving the light of the moon upon white paper : the light of a clear day reflected into the shade by snow, is of a fine blue, according to the observations of Daniel Major (*Ephem. des Curios. de la Nature*, 1671, premier Dec.).

The colouring principle is found in vegetables in four states of combination—1. With the extractive principle. 2. With the resinous principle. 3. With a fecula. 4. With a gummy principle.—These four states in which we find the colouring principle, indicate to us the means of extracting it.

A. When the receptacle of the colour is of the nature of extracts, water is capable of dissolving the whole : such is that of logwood, turnsole, madder, cochenille, &c. Nothing more is necessary than to infuse these substances in water, for the purpose of extracting their colouring principle. If any stuff be plunged in this solution, it will be covered with

a body of colour, which will be a mere stain, that may be again cleared off by water. To obviate this inconvenience, it has therefore been found necessary to impregnate the stuffs on which the colours were intended to be applied with some salt, or other principle, which might change the nature of the colouring matter, and give it fixity, by depriving it of its solubility in water. It is this substance which is distinguished by the name of Mordant. It is likewise necessary that the mordant should have an affinity with the principle of colour; in order that it may become its receiver. Hence it arises that most of these colours, such as turnsole, Brasil wood, &c. are not fixed by these mordants; hence also it arises that cochenille does not form a fine scarlet, unless it has tin for its mordant. It is necessary, moreover, that the mordant have a due relation to the nature of the stuff; for the same composition which gives a fine scarlet colour to wool, gives a colour of wine lees to silk, and does not even change the white colour of cotton.

B. There are certain resinous colouring matters soluble in spirit of wine: such are the pharmaceutical tinctures: they are used only in the arts for dyeing ribbons. There are other colouring matters combined with feculæ, which water does not dissolve: rocou, archil, indigo, and the red colour of oriental saffron, are of this kind.

Rocou is a resinous fecula obtained by macerating the seeds of an American tree called Urucu in water. In this operation the extractive part is destroyed by fermentation, and the resinous fecula is collected in a paste of a deep yellow colour. The paste of rocou, diffused in water with the impure alkali called *cendres gravelées*, affords a fine orange colour.

Archil is a paste prepared by macerating certain mosses and lichens in urine with lime. Alkalis extract a violet colour. Archil is made in Corsica, in Auvergne, at Lyons, &c.

The Archil of the Canaries is less charged with lime. That which I procured, exhibited in its texture the fibres of the plant, not completely decomposed by the fermentation. The archil of the Canaries, or the archil in the herb, is afforded by a lichen called, *Orcella*, *rocella*, *lichen fruticosus*, *solidus*, *aphyllus*, *subramosus*, *tuberculis alternis*, Linnæi.

The parella or archil of Auvergne is made with the *lichen parellus* Linnæi.

The colouring matters of this class are all soluble in alkali or lime; and these are the substances used to dissolve them in water, and precipitate them upon stuffs. Lime is the true solvent of indigo; but alkali is the solvent of other substances of the same class. For example: when it is required to make use of the colouring matter of bastard saffron, the first proceeding consists in washing it in much water, to clear it of the extractive and yellowish principle, which is very abundant; and the resinous principle is afterwards dissolved by means of alkali, from which solvent it is precipitated upon the stuffs by means of acids. In this manner it is that the poppy-coloured silk is made. This resinous principle may also be combined with talc, after it has been extracted by an alkali, and precipitated by an acid; in which case the result is vegetable red. To make this pigment, the yellow colour of saffron or carthamus is first extracted by means of washing. Five or six per cent. of its weight of soda is mixed with the residue; and cold water poured on, which takes up a yellow matter; and this, by the addition of lemon juice, deposits a red fecula. The red fecula, mixed with levigated talc, and moistened with lemon juice, forms a paste, which is put into pots to dry. If the red be soluble in spirit of wine, it is vegetable; but if not it is mineral, and is usually vermilion.

Acids may be used instead of alkalis in fixing some of these colours upon stuffs. To make a permanent blue, instead of dissolving indigo by means of lime, it is sometimes dissolved in oil of vitriol. This solution is poured into the bath, and the alumed stuff is passed through it. Flannels are died blue at Montpellier in this way. This operation depends merely on an extreme division of the indigo by the acid.

D. There are some colouring principles fixed by a resin; but which, by the assistance of extractive matter, may be suspended by water. The stuffs are boiled in this solution; the resinous part applies itself to them, and adheres with sufficient solidity not to be again carried off by water.

No preparation is required to dye with these ingredients, nothing more being necessary than to boil the stuff in a



decoction of the colour. The principal substances of this kind are, the husk of walnuts, the roots of the walnut tree, sumach, fantal, the bark of elder, &c. All these substances, which require no mordants, afford only a buff-coloured tinge, which dyers call Root Colours. The colouring matter of certain vegetables may likewise be extracted by oils. In this way oils are coloured red by infusing alkanet, or the root of a certain species of bugloss, in them.

In order to apply colouring matter properly upon any stuff, it is necessary to prepare the stuff, and dispose it to receive the colouring principle. For this purpose it must be washed, bleached, and cleared of that glutinous matter which defends it from the destructive action of the air while it grows on the animal which affords it; and impregnated with the mordant which fixes the colour, and gives it peculiar properties.

A. The first operation required to dispose a stuff to receive colour, is bleaching; because the whiter it is, the more natural and accurate will be the colour it takes. If this precaution be not taken, the success will be uncertain. To bleach piece-goods, the operator is satisfied with boiling them in an alkaline lixivium, and exposing them afterwards to the air, to render the whiteness more perfect. This operation depends on the action of the oxigene, which combines with the colouring principle, and destroys it; as is evidently demonstrated by the late experiments of M. Berthollet on the oxigenated muriatic acid, which bleaches cloths and cottons with such facility, that it is already used for this purpose in several manufactories.

Cotton is bleached in some manufactories by a very ingenious process. A boiler is firmly set in masonry, and a cover fitted to it in the strongest manner; this boiler has an elliptical figure. Alkali rendered caustic by lime is put into the bottom of this vessel; and the goods intended to be bleached are put into a basket which prevents their touching the sides of the boiler. When the piece-goods are properly placed, the covering is fixed on, which is pierced by a very small aperture, to permit a portion of the aqueous vapour to escape. A degree of heat much superior to that of boiling water is excited in the solution of pot-ash: and



the heat, assisted by the corrosive action of the pot-ash in this kind of Papin's digester, destroys the colouring principle of the cottons, and gives them the utmost whiteness.

B. That kind of gluten which envelopes almost every animal substance, but more especially raw silk, is insoluble in water and in alcohol. It is only attacked by alkalis and soaps; and for this purpose the operation of cleansing is used. Any stuff may be cleared of its glutinous part by boiling or even digesting it in a solution of alkali: but it has been observed that a pure alkali alters the goodness and quality of the stuff; for which reason soaps have been substituted in its stead. For this purpose the stuff is steeped in a solution of soap, heated to a less degree than boiling. The academy of Lyons, in the year 1761, proposed a prize for the means of clearing raw silks without soap. It was adjudged to M. Rigaut, of St. Quentin, who proposed a solution of salt of soda.

It has been lately ascertained that water, heated above the degree of ebullition, is capable of dissolving this colouring principle. A boiler similar to that which I have just described, may be used for this purpose.

In order to bleach cotton, and dispose it for the dying processes, it is cleansed by means of a liquid soap made of oil and soda.

The piece-goods are cleared by this boiling from the varnish, which would prevent the colour from applying and fixing itself in a permanent manner; at the same time that it opens the pores of the stuff for the better reception of the colour.

When the piece is thus prepared, its pores being very open, and its colour very white, nothing remains to be done previous to the application of the dye, but to impregnate it with the mordant or principle which is to receive the colour and change its nature so much, that neither water, soap, nor any of the reagents used as proofs, may be capable of extracting it. It is necessary therefore—1. That the mordant itself should be very white, that it may not alter the colour presented to it. 2. That it be not subject to corruption; and for this purpose it must be sought among the earths and metallic oxides. 3. That it be in a state of extreme division, in order that it may fix itself in the pores. 4. That

it be insoluble in water and the other reagents. 5. That its affinity with the colouring matter and the stuff be very great.

Alum and the muriate of tin, are the two salts whose bases unite these properties in the most efficacious manner. The stuffs having undergone the previous operations are therefore steeped in solutions of these salts; and when they are impregnated, they are passed through the colouring bath; and by the decomposition, or change of principles between the mordant and the principle which holds the colour in solution, the colour is precipitated on the base of the mordant, and adheres to it.

Certain vegetable substances are likewise disposed to take some colours by animalizing them. In this way cows dung and bullocks blood are used in dyeing cotton; for it is a decided fact that animal substances take colours better than vegetables.

#### ARTICLE XII.

Concerning the Pollen, or Fecundating Powder of the Stamina of Vegetables.

Modern discoveries and observations have pointed out the sexual parts of plants; and we find nearly the same forms in the organs, the same means in the functions, and the same characters in the prolific humours, as in animals.

The prolific humour in the male part is elaborated by the anthera: and as the organs of the plant do not admit of an actual intromission of the male into the female, because vegetables are not capable of loco-motion, nature has bestowed on the fecundating seed the character of a powder; which the agitation of the air, and other causes, may carry away and precipitate upon the female. There is a degree of elasticity in the anthera, which causes it to open, and eject the globules. It has even been observed that the pistil opened at the same time, to receive the pollen, in certain vegetables. The resources of nature to assure the fecundation are admirable. The male and female parts almost always repose in the same flower; and the petals are always disposed in the most advantageous manner to favour the reproduction of the species. Sometimes the male and female are upon the same individual, but placed upon different flowers; at other times both are attached to isolated and separate

individuals, and then the fecundation is made by the pollen which the wind or air detaches from the antheræ, and transmits to the female.

The fecundating powder has almost constantly the smell of the spermatic liquor of animals. The smell of cabbages in blossom, of the chestnut tree, and most other vegetables, exhibits this analogy to such a degree, that the one odour might even be mistaken for the other.

The pollen is generally of a resinous nature, soluble in alkalis and in alcohol. Like resins, it is inflammable; and the *aura* which is formed around certain vegetables at the time of fecundation, may be set on fire, as was observed by Mademoiselle Linné in the *fraxinella*.

Nature, which has employed less œconomical means in the fecundation of plants, and who entrusts these operations almost to chance, since she delivers the fecundating powder to the winds, must of course have been prodigal in the formation of this humour; more especially for the trees of the monoecia and dioecia genera, where the production is more exposed to accidental impediments. Hence we may account for those pretended showers of sulphur, which are never common but in such districts as abound with the hazel, filbert, and pine-trees.

As the pollen could not be exposed by nature to the varying temperatures of the atmosphere, she has facilitated its development in the most rapid manner. A warm sun very frequently suffices to open the concealed organs of the plant, to develope and procure its fecundation. On this account the author of *Les Etudes de la Nature* affirms, that the coloration of plants is designed to reflect the light more vividly, and that most flowers affect the most advantageous form to concentrate the solar rays on the parts of generation.

The parts employed in these functions are endued with an astonishing degree of irritability. M. des Fontaines has made some very interesting observations on this subject; and the agitated motions which some plants affect in order to follow the course of the sun, are determined by nature, in order that the great work of generation, favoured by the sun, may be accomplished in the least possible time.



## Concerning Wax.

The wax of bees is merely the pollen very little altered. These insects have their *femurs* provided with rugosities to brush the pollen from the antheræ, and convey it to their nests.

There appears to exist in the very texture of some flowers, which are rich in fecundating powder, a matter analogous to wax, which may be extracted by aqueous decoction. Such are the male catkins of the *betula alnus*, those of the pine, &c. the leaves of rosemary, of officinal sage, the fruits of the *mirica cerifera*, suffer wax to transude through the pores.

It appears that wax and the pollen have for their basis a fat oil, which passes to the state of resin by its combination with oxigene. If the nitric or muriatic acid be digested upon fixed oil for several months, it passes to a state resembling wax.

Wax by repeated distillations, affords an oil which possesses all the properties of volatile oils. It is reduced into water and carbonic acid by combustion.

The colouring matter of wax appears to be of the same nature as that of silk; it is insoluble in water and in alcohol. In the arts, wax is bleached by dividing it prodigiously; for which purpose oil is poured in fusion upon the surface of a cylinder, which revolves at the surface of water. The wax which falls applies itself to the superficies, and is reduced into very thin flakes or ribbons. It is afterwards exposed to the air upon tables, taking care to stir it from time to time, and by this means it becomes white.

Alkalis dissolve wax, and render it soluble in water. It is this saponaceous solution which forms the Punic wax. It may be used as the basis of several colours; and may be made into an excellent paste for washing the hands. It is likewise applied with a brush upon several bodies: but it would be highly advantageous if it could be deprived of its solvent, which constantly acts, and is the cause why it cannot be applied to several uses, in which otherwise it might be found advantageous.

Ammoniac likewise dissolves it; and as this solvent is evaporable, it ought to be preferred when it is proposed to use the wax as a varnish.



## ARTICLE XIII.

## Concerning Honey.

Honey, or the nectar of flowers, is contained chiefly in the base of the pistil, or female organ. It serves as food for most insects which have a proboscis. These animals plunge their proboscis into the pistil, and suck out the nectar. It appears to be a solution of sugar in mucilage; the sugar is sometimes precipitated in crystals, as in the nectar of the flower of balsamina.

The nectar undergoes no alteration in the body of the bee, since we can form honey by concentrating the nectar. It retains the odour, and not unfrequently the noxious qualities of the plant which affords it.

The secretion of the nectar is made during the season of fecundation. It may be considered as the vehicle and recipient of the fecundating dust, which facilitates the bursting of the globules, filled with this fecundating powder: for Linnaeus and Tournefort have both observed that nothing more is required than to expose the pollen upon water, to assist the development. All the internal part of the style of the pistil is impregnated with it. And if the internal part of the female organs be dried by heat, the pollen no longer fecundates.

Honey exsudes from all the female parts, but particularly from the ovaria. Pores may even be observed in hyacinths, through which it flows.

Such flowers as have only the male parts do not in general afford honey; and the organs which afford the nectar dry up and wither from the moment the act of conception is accomplished. Honey may therefore be considered as necessary to fecundation; it is the humour afforded by the female to receive the fecundating powder, and facilitate the opening and explosion of the small bodies which contain the pollen; for it has been observed that these bodies open the moment they touch the surface of any liquid which moistens them.

## ARTICLE XIV.

## Concerning the Ligneous Part of Vegetables.

Chemists have constantly directed their attention to the analysis of vegetable juices: but they appear to have com-

pletely neglected the solid part of the vegetable, which in every point of view is entitled to particular attention. It is this ligneous portion which forms the vegetable fibre; and this matter not only constitutes the basis of the vegetable, but is likewise developed in circumstances which depend on the vital functions of the plant. It forms the pulp of seeds, the lanuginous covering which overspreads certain plants, &c. The character of the ligneous part is, an insolubility in water and almost every other menstruum. The sulphuric acid only blackens it, and is decomposed upon it, as is likewise the nitric acid. But one very peculiar character of this principle is, that the concurrence of air and water alters it very difficulty; and that, when it is well deprived of all its moisture, it absolutely resists every kind of fermentation; insomuch that it would be indestructible, if insects had not the property of gnawing and feeding upon it. It appears that the vegetable fibre consists of the basis of mucilage, hardened by its combination with a greater quantity of oxigene. Several reasons lead us to adopt this idea. In the first place, the diluted nitric acid being put to digest upon fecula is decomposed, and causes the fecula to pass to a state resembling that of ligneous matter. I have observed, in the second place, that those fungi which grow in subterraneous places void of light and are resolved into a very acid water, if left in a vessel, acquire a greater quantity of the ligneous principle, in proportion as they are exposed by degrees to the light; at the same time that the acid is diminished by decomposition, and at length disappears.

The transition of mucilage to the state of ligneous matter is very evident in the growth of vegetables. The cellular envelope which is immediately covered by the epidermis exhibits nothing but mucilage and glands; but by degrees it hardens, forms a stratum of the cortical coating, and at last concludes by becoming one of the ligneous rings.

We observe this transition in certain plants which are annual in cold climates, and vivacious in temperate climates. In the former they are herbaceous, because the periodical return of the cold weather does not permit them to develop themselves. In the second they become arboresecent; and the progress of time hardens the mucilage, and forms ligneous coatings.

The induration of the fibrous part may be accelerated by causing the air and light to act more strongly upon it. M. de Buffon has observed that, when a tree is deprived of its bark, the external part of the wood which is exposed to the air acquires a considerable degree of hardness; and trees thus prepared form pieces of carpentry much more solid than those which have not undergone such preparation.

It is probably owing to the large quantity of pure air with which the fibrous matter is loaded, that it is not disposed to putrefy: and it is in consequence of this most valuable property of not being subject to corruption, that arts have been invented for clearing it of all fermentable principles of the vegetable kingdom, to obtain it in its greatest purity in the fabrication of cloths, paper, &c. We shall again return to these objects, when we treat of the alterations to which the vegetable kingdom is subject.

#### ARTICLE XV.

Concerning other fixed Principles of the Vegetable Kingdom.

The volatile oil of horse-radish had formerly afforded sulphur, which is deposited by standing, according to the observations of some chemists; but M. Deyeux has taught us to extract this inflammable principle from the root of the herb patience. Nothing is required to be done but to rasp the root, boil, take off the scum, and dry it. This scum affords much sulphur in substance; and it is perhaps to this principle that these plants owe their virtue, since they are used in skin disorders.

Vegetables in their analysis likewise present us with certain metals, such as iron, gold, and manganese. The iron forms near one-twelfth of the weight of the ashes of hard wood, such as oak. It may be extracted by the magnet. It does not appear to exist in a perfectly disengaged state in the vegetable; nevertheless we read, in the *Journaux de Physique*, an observation in which it is affirmed, that it was found in metallic grains in fruits. The iron is usually held in solution in the acids of vegetation, from which it may be precipitated by alkalis. The existence of this metal has been attributed to the wearing of ploughshares, and other instruments of husbandry, and to the faculty which plants possess



of imbibing it with their nutritive juices. The Abbé Nollet and others have embraced this unphilosophical notion. It is the same with the iron as with the other salts. They are produced by vegetation; and vegetables watered with distilled water afford it as well as others.

Beccher and Kunckel ascertained the presence of gold in plants. M. Sage was invited to repeat the processes by way of ascertaining the fact. He found gold in the ashes of vine twigs, and announced it to the public. After this chemist, most persons who have attended to this object have found gold; but in much less quantity than M. Sage had announced. The most accurate analyses have shewn no more than two grains; whereas M. Sage had spoken of several ounces in the quintal. The process for extracting gold from the ashes consists in fusing them with black flux and minium. The lead which is produced is then cupelled, to ascertain the small quantity of gold with which it became alloyed in this operation.

Scheele has also obtained manganese in the analysis of vegetable ashes. His process consists in fusing part of the ashes with three parts of fixed alkali, and one-eighth of nitrate of pot-ash. The fused matter is boiled in a certain quantity of water. The solution being then filtered, is saturated with sulphuric acid, and at the end of a certain time manganese falls down.

Lime constantly enough forms seven-tenths of the fixed residue of vegetable incineration. This earth is usually combined with the carbonic acid. Scheele has proved that it effloresces in this form on the bark of guaiacum, the ash, &c. It is likewise very often united with the acid of vegetation. It appears to be formed by an alteration of the mucilage, more advanced than that which forms the secula, which has some analogy with this earth. We evidently see the transition of mucilage to the state of earth in testaceous animals. We observe the mucilage putrefy at its surface, with so much the more facility as it is purer; as we may judge by a comparison of the *alteriæ*, the sea hedge-hog, the crab, &c.

Next to lime, alumine is the most abundant earth in vegetables, and next magnesia. M. Darcet has obtained, from one pound of the ashes of beech, one ounce of the sulphate of magnesia, by treating them with the sulphuric acid. This



earth is very abundant in the ashes of tamarisc. Siliceous earth likewise exists, but less abundantly. The least common of all is the barytes.

## ARTICLE XVI.

Of the common Juices extracted by Incision or Expression.

The vegetable juices hitherto treated of are peculiar substances contained in vegetables, and possessing striking characters, by which they are distinguishable from every other humour. But we may at once extract from vegetables all the juices they contain; and this mixture of various principles may be obtained by several methods. Simple incision is sometimes sufficient; but expression is equally used.

The juices of vegetables vary according to the respective nature of the plants. They are more abundant in some than in others. Age modifies them. Young trees in general have most sap; and this sap is milder, more mucilaginous, and less charged with oil and resin. The sap varies according to the season. In the spring the plants draw up with avidity the juices afforded by the air and the earth; these juices establish a plethora every where, from which results a considerable growth of the individual, and sometimes a natural extravasation. If in the time of plethora incisions be made in any part of the vegetable, all the abundant sap escapes by the aperture; and this fluid is almost always clear, and without smell. But by degrees the plant elaborates these juices, and gives them peculiar characters. In the spring the sap in the body of the vegetable presents only a slight alteration of the nutritive juices; but in the summer the whole is elaborated, all is digested, and then the sap possesses characters very different from those it possessed during the spring season. If incisions be now made in the tree, the juices obtained are accordingly very different; and for this reason it is that the juices dispersed in commerce are extracted during the summer.

The constitution of the air equally influences the nature of vegetable juices. A rainy season opposes the development of the saccharine principle, as well as the formation of resins and aromatic substances. A dry season affords little mucilage, but much resin and aromatic principle; hot weather decomposes the mucilage, and favours the development of resins, saccharine matter, and aroma; but a cold season does

not permit the formation of any principle but mucilage: and as the mucilage is the principle of increase of bulk in plants, the whole of this substance is employed for that purpose; while the heat and light modify the same mucilage, and cause it to pass to the state of oil, resin, aroma, &c. Hence probably it is that trees have a more agreeable appearance in cold than in burning climates; and that the trees in this latter situation abound with aromatic, oily, and resinous principles. In the vegetable as in the animal kingdom, spirit appears to be the portion of the southern climates; while force and strength are attributes of the northern.

Concerning the Juices extracted by Incision.

The juice contained in plants, and known by the name of Sap, is dispersed through the cellular tissue, inclosed in the vessels, or deposited in the utricles: and there is a communication existing, which, when any part of the vegetable is wounded, causes the abundant juices to flow through the aperture; not indeed so speedily, nor so completely, as in animals; because the humours do not possess so rapid a motion, and because there is less connection between the several organs in vegetables than in animals. The sap is a confused mixture of all the principles of vegetables. The oil and the mucilage are confounded with the salts. It is, in a word, the general humour of vegetables, in the same manner as the blood in animals. In the present place we shall speak only of manna and opium.

I. Manna.—Several vegetables afford manna; and it is extracted from the pine, the fir, the maple, the oak, the juniper, the fig, the willow, the olive, &c. but the ash, larch, and the alhagi, afford it in the largest quantities. L'obel, Rondelet, and others, have observed at Montpellier, upon the olive trees, a kind of manna, to which they have given the name of *celiomeli*. Tournefort collected it from the same trees at Aix, and at Toulon.

The ash which affords manna grows naturally in all temperate climates; but Calabria and Sicily appear to be the most natural countries to this tree; or at least it is only in these countries that it abundantly furnishes the juice called Manna in commerce.

The manna flows naturally from this tree, and attaches itself to its sides in the form of white transparent drops; but

the extraction of this juice is facilitated by incisions made in the tree during summer: the manna flows through these apertures upon the trunk of the tree, from which it is detached with wooden instruments. Care is likewise taken to insert straws, or small sticks of wood, into these incisions; and the stalactites which hang from these small bodies are separated, and known in commerce by the name of Manna in Tears: the smallest pieces form the manna in forts or flakes; and the common or fat manna is of the worst quality, because the most contaminated with earth and other foreign substances. The ash sometimes affords manna in our climates, specimens of which I have seen collected in the vicinity of Aniane.

The larch which grows abundantly in Dauphiny, and the environs of Briançon, likewise affords manna. It is formed during the summer on the fibres of the leaves, in white friable grains, which the peasants collect and put into pots, which they keep in a cool place. This manna is of a yellow colour, and has a very nauseous smell.

The alhagi is a kind of broom, which grows in Persia. A juice transudes from its leaves, in the form of drops of various sizes, which the heat of the sun indurates. An interesting account of this tree may be seen in Tournefort's Travels. This manna is known in the Levant, in the town of Tauris, by the name of Tereniabin.

The manna most frequently used is that of Calabria. Its smell is strong, and its taste sweetish and nauseous: if exposed on hot coals, it swells up, takes fire, and leaves a light bulky coal.

Water totally dissolves it, whether hot or cold. If it be boiled with lime, clarified with white of egg, and concentrated by evaporation, it affords crystals of sugar.

Manna affords by distillation water, acid, oil, and ammoniac; and its coal affords alkali.

This substance forms the basis of most purgative medicines.

2. Opium.—The plant which affords opium is the poppy, which is cultivated in Persia and Asia Minor. To extract this precious medicine, care is taken to cut off all the flowers which would load the plant, and to leave that only which corresponds with the principal stem. At the beginning of summer, when the poppy-heads are ripe, incisions are made



quite round them, from which tears flow that are carefully collected. This opium is the purest, and is retained in the country for various uses. That which comes to us is extracted by pressure from the same heads. The juice thus obtained is wrapped up, after previous drying, in the leaves of the poppy, and comes to us in the form of circular flattened cakes.

In our laboratories it is cleared from its impurities by solution in hot water, filtration, and evaporation to the consistence of an extract. This is the extract of opium.

Opium contains a strong and narcotic aroma, from which it is impossible to clear it, according to Mr. Lorry. It likewise contains an extract soluble in water, and a resin; together with a volatile concrete oil, and a peculiar salt.

By long digestion in hot water the volatile oil becomes attenuated, is disengaged, and carries the aroma with it; so that by this means the oil and aroma may be separated, at least for the most part. It has been observed that opium deprived of this oil, a portion of its aroma, and its resin, preserved its sedative virtue, without being narcotic and stupifying. We are indebted to Baumé for a series of interesting researches on this subject. He boiled four pounds of sliced opium in between twelve and fifteen pints of water, for half an hour. The decoction was strained with pressure, the dregs were exhausted by ebullition with more water. All these waters were mixed together, and reduced by evaporation to six pints. The liquor was then put into a cucurbit of tin, and digested on a sand-bath for six months, or during three months night and day. Care was taken to add water as the evaporation proceeded; and the bottom of the vessel was scraped from time to time, to disengage the resinous matter which subsided. When the digestion was finished, the liquor was filtered, the residue carefully separated, and the water evaporated to the consistence of an extract.

If the salt be required to be separated, the evaporation must be suspended when the fluid is reduced to one pint. An earthy salt falls down by cooling, which is of a ruddy appearance, and has the form of scales mixed with needled crystals.

By this long but judicious process, the oil is first separated; which after three or four days rises to the surface of the



liquor, where it forms an adhesive pellicle, like turpentine. This pellicle is gradually dissipated, and disappears at the end of a month, nothing more being seen than a few drops from time to time. In proportion as the oil is dissipated, the resin, which formed a soap with it, is precipitated.

Mr. Baumé has calculated that these principles exist in the following proportions:—Four pounds of common opium afford one pound one ounce of marc or insoluble matter, one pound fifteen ounces of extract, twelve ounces of resin, one gros or dram of salt, three ounces seven gros of dense oil or aroma.

Mr. Bucquet proposed to extract the sedative principle, by dissolving it in the cold, and afterwards evaporating it; Mr. Josse, by agitating it in cold water; Messrs. De Lassone and Cornette, by dissolving, filtering it several times, and always evaporating it to the consistence of an extract.

The sedative principle is a medicine of the greatest value, because it does not produce that drunkenness and stupor which are too commonly the effects of crude opium.

When a plant does not afford its juice by incision, this may happen either because the quantity is too small, or because its consistence is not sufficiently fluid, or because there is not a sufficiently perfect communication between the vessels of the plant to permit the flowing of all the juice. In these cases the desired effect may be produced either by simple mechanical pressure, as in extracting the juice of hypocistis and acacia; or by the assistance of water, which softens the texture of the vegetable, at the same time that it dissolves and carries off the juice.

#### Concerning Vegetable Juices extracted by Pressure.

The succulent vegetables afford their juice by simple pressure; and the method of performing this operation is nearly the same in all plants. When it is intended to extract the juice of a plant, it is washed, cut into small pieces, pounded in a marble mortar, put into a linen bag, and pressed in a press.

There are some ligneous plants, such as sage, thyme, and the lesser centaury, whose juices cannot be extracted without the addition of a small quantity of water; there are other very succulent plants, such as borage, bugloss, and chicory,

whose juices are so viscid and mucilaginous, as not to pass through a cloth unless a small quantity of water be added during the pounding. Inodorous plants may likewise be left to macerate, in order to prepare them for the extraction of their juices. The vegetable juices may be clarified by simple repose, or by filtration; when very fluid, by white of egg, or animal lymph, boiled with them; and when the juices contain principles which may be evaporated, such as those of sage, balm, marjoram, &c. the vial which contains the juice is plunged in boiling water, after having closed it with a paper with a hole pierced through it; and when the juice is clarified, it is taken out, dipped in cold water, and decanted.

The juice of acacia is extracted from the same tree which affords gum arabic. The fruits of this tree are collected before they are ripe; then pounded, pressed, and the juice dried in the sun: it forms balls of a blackish brown internally, redder externally, and of an astringent taste.

A juice is prepared with unripe sloes, which is sold under the name of German Acacia, and does not differ much from that of Egypt.

The juice of hypocistus is extracted from a parasitical plant which grows on the cistus in the island of Crete. The fruit is pounded, the juice extracted by pressure, and thickened in the sun; it becomes black, and of a firm consistence.

These two last-mentioned juices are used in medicine as astringents.

#### SECTION IV.

Concerning such Principles as escape from Vegetables by Transpiration.

**V**EGETABLES being endued with digestive organs, throw off all such principles as cannot be assimilated by them; and when the functions of the vegetable are not favoured by such causes as facilitate them, the nutritive juices are rejected nearly unaltered. We shall here attend to three principal substances that exhale from vegetables, viz. air, water, and aroma.

## ARTICLE I.

Concerning Oxygenous Gas afforded by Vegetables.

Dr. Ingenhoufz published, in the year 1779, Experiments upon Vegetables, in which he affirms that plants possess the property of emitting vital air when acted upon by the direct rays of the sun; and that they emit a very mephitic air in the shade, and during the night.

Doctor Priestley made known the same results at the same time, as well as Mr. Senebier of Geneva, who nevertheless did not publish a work on this subject until the year 1782, in which he admits, as a general principle, that plants suffer vital air to escape in the sun-shine: but he maintains that they do not produce mephitic air in the shade; and is of opinion that, if Dr. Ingenhoufz obtained any, it arose from a commencement of putrefaction in the plant.

The simplest process for extracting this gas from vegetables, consists in immersing them under water, beneath an inverted glass vessel. It is then seen, when the sun acts on the plant, that small bubbles are emitted, which gradually grow larger, arise from the fibres of the leaf, and ascend to the surface of the fluid.

All plants do not afford gas with the same facility. There are some which emit it the moment the sun acts upon them: such are the leaves of the jacobæa, of lavender, and of some aromatic plants. In other plants the emission is slower; but in none later than seven or eight minutes, provided the sun's light be strong. The air is almost totally furnished by the inferior surface of the leaves of trees: it is not the same with herbs; for these afford air from nearly the whole of their surface, according to Senebier.

The leaves afford more air when attached to the plant than when gathered; and the quantity is likewise greater the fresher and sounder they are.

Young leaves afford but a small quantity of vital air; those which are full grown afford more, and the more the greener they are. Leaves which are injured, yellow, or red, do not afford it.

Fresh leaves cut in pieces afford air; and the oxygen gas is capable of being emitted without the plant being plunged under water, as is proved from the experiments of Mr. Senebier.

The parenchyma of the leaf appears to be the part which emits the air. The epidermis, the bark, and the white petals, do not afford air; and in general it is only the green parts of plants which afford oxygenous gas. Green fruits afford air, but those which are ripe do not; and the same is true of grain.

It is proved that the sun does not act in the production of this phenomenon as a body which heats. The emission of this gas is determined by the light; and I have even observed that a strong light, without the direct action of the sun's rays, is sufficient to produce this phenomenon.

It is proved, by the experiments of Mr. Senebier, that an acid diluted in water increases the quantity of air which is disengaged, when the water is not too much acidulated; and in this case the acid is decomposed.

It has been observed that the conserva affords much vital air; as well as the green matter which is formed in water, and is supposed by Ingenhoufz to be a collection of greenish insects.

Pure air is therefore separated from the plant by the action of light; and the excretion is stronger accordingly as the light is more vivid. It seems that light favours the work of digestion in the plant; and that the vital air, which is one of the principles of almost all the nutritive juices, more especially of water, is emitted, when it finds no substance to combine with in the vegetable. Hence it arises that plants whose vegetation is the most vigorous, afford the greatest quantity of air: and hence likewise it is that a small quantity of the acid mixed with the water favours the emission and increases the quantity of oxygenous gas.

By this continual emission of vital air, the Author of nature incessantly repairs the loss which is produced by respiration, combustion, and the alteration of bodies, which comprehends every kind of fermentation and putrefaction; and in this manner the equilibrium between the constituent principles of the atmosphere is always kept up.

## ARTICLE II.

Concerning the Water afforded by Vegetables.

Plants likewise emit a considerable quantity of water, in the form of vapour, through their pores; and this excretion



may be estimated as the most abundant. Hales has calculated that the transpiration of an adult plant, such as the *helianthus annuus*, was in summer seven times more considerable than that of man.

Guettard has observed that this excretion is always in proportion to the intensity of the light, and not of the heat; so that there is scarcely any during the night. The same philosopher has observed that the aqueous transpiration is more especially made from the upper surface of the leaf. The water which exhales from vegetables is not pure, but serves as the vehicle of the aroma; and even carries with it a small quantity of extractive matter, which causes it to corrupt so speedily.

The immediate effect of the aqueous evaporation consists in maintaining a degree of coolness in the plant, which prevents its assuming the temperature of the atmosphere.

### ARTICLE III.

Concerning the Aroma, or Spiritus Rector.

Each plant has its characteristic smell. This odorant principle was distinguished by Boerhaave by the name of Spiritus Rector, and by the moderns under the name of Aroma.

The aroma appears to be of the nature of gas, from its fineness, its invisibility, &c. The slightest heat is sufficient to expel it from plants. Coolness condenses it, and renders it more sensible; and on this account the smell of plants is much stronger in the morning and evening.

This principle is so subtle, that the continual emission of it from a wood or flower does not diminish its weight, even after a very considerable time.

The aroma is sometimes fixed in an extract, sometimes in an oil, and this last combination is the most usual. It even appears to constitute the volatile character of the essential or volatile oils.

The nature of the aroma appears to vary prodigiously; at least if we may judge by the organ of smell, which distinguishes several species. There are some which have a nauseous or poisonous effect on the animal œconomy. Ingenhoufz quotes an instance of the death of a young woman occasioned by the smell of lilies, in 1719; and the famous Triller reports the example of a young woman who died in

consequence of the smell of violets, while another was saved by removing the flowers. Martinus Cromerus exhibits likewise an example of a bishop of Breslau who died by a similar cause.

The mancenille tree which grows in the West-Indies, emits very dangerous vapours. The humour which flows from this tree is so unwholesome, that if it drop on the hand it raises a blister.

The American plant *lobelia longiflora* produces a suffocating oppression in the breast of those who respire in its vicinity, according to Jacquin, *Hortus Vindobonensis*. The *rhus toxicodendron* emits so dangerous an exhalation, that Ingenhoufz attributes the return of a periodical disorder, which attacked the family of the curate of Crossen in Germany, to a bench shaded by this tree, under which they had the custom of sitting. Every one knows the effects of musk and oriental saffron on certain persons; and the exhalation of the walnut-tree is considered as very unwholesome.

We may here mention the noxious property of those canes or reeds which in this country are used to cover roofs and dunghills, &c. Mr. Poitiven saw a man who was very ill on account of having handled these canes: the parts of generation were prodigiously swelled. A dog which had slept upon the reeds suffered in the same manner, and was affected in the same parts.

The method of extracting the aroma varies according to its volatility and affinities. It is in general soluble in water, alcohol, oils, &c. and these fluids are severally employed to extract it from plants which afford it.

When water or alcohol are used, they are distilled by a gentle heat, and the aroma comes over with them. Simple infusion may be used; and in this way the loss of a portion of the aroma is avoided.

Water charged with aroma is known by the name of the distilled water of the substance made use of. The distilled water of inodorous or herbaceous plants does not appear to possess any virtue; and the apothecaries have long since decided the question, by substituting spring water in its place. Spirit of wine combined with the same principle, is known by the name of the spirit or quintessence of the vegetable.

When the aroma is very fugacious, such as that of lilies, jasmine, or tuberoſe, the flowers are put into a tin cucurbit with cotton ſteeped in oil of ben. The cotton and the flowers are diſpoſed in alternate layers; the cucurbit is cloſed, and a gentle heat applied. In this manner the aroma is permanently combined with the oil.

Theſe are the three methods uſed to retain the odorant principle. The art of the perfumer conſiſts in applying them at pleaſure to various ſubſtances.

Perfumes are either dry or liquid. Among the firſt we may place the ſachets, or little perfumed bags, which contain either mixtures of aromatic plants, or aromas in their native ſtate; the perfumed powders, which obtain their ſmell by a few drops of the ſolution of aroma; the paſtilles or comfits which have ſugar for their baſis, &c.

Liquid perfumes moſt commonly conſiſt of aroma diſſolved in water or alcohol; the various liqueurs, or ſcented ſpirituous cordial waters, are nothing elſe but the ſame ſolutions diluted with water, and ſweetened with ſugar.

For example, to make the eau divine, the bark of four citrons is taken, and put into a glaſs alembic, with two pounds of good ſpirit of wine, and two ounces of good orange flower water; after which, diſtillation is performed on the ſand-bath. On the other hand, one pound and a half of ſugar is diſſolved in one pound and a half of water. The two liquors being mixed, become turbid; but, being left to ſtand, the reſult is an agreeable liquor.

To make the cream of roſes, I take equal parts of roſe water, ſpirit of wine à la roſe, and ſyrup of ſugar. I mix theſe three ſubſtances, and colour the mixture with the infuſion of cochenille.

But it muſt be allowed that, in all perfumes which are a little complicated, the noſe is the beſt chemiſt that can be conſulted; and a good noſe is as requiſite and eſſential to a perfumer, as a ſtrong head is to a geometer.

## SECTION V.

Concerning the Alterations to which Vegetables are subject after they are deprived of Life.

THE same principles which maintain life in vegetables and animals, become the speediest agents of their destruction when dead. Nature seems to have entrusted the composition, maintenance, and decomposition of these beings to the same agents. Air and water are the two principles which maintain the life in living beings; but the moment they are dead they hasten their alteration and dissolution. The heat itself, which assisted and fomented the functions of life, concurs to facilitate the decomposition. Thus it is that the frosts of Siberia preserve bodies for several months; and that in our mountains they are kept for a long time on the snow, when it intercepts the carrying them to the place of interment.

We shall examine the action of these three agents, namely heat, air, and water; and we shall endeavour to shew the power and effect of each before we shall attend to their combined action.

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 C H A P. I.

Concerning the Action of Heat upon Vegetable Substances.

THE distillation of plants by a naked fire is nothing but the act of decomposing them by means of simple heat. This process was for a long time the only method of analysis. The first chemists of Paris adopted it for the analysis of near one thousand four hundred plants: and it was not till the commencement of the present century that this labour was discontinued; a labour which did not seem to advance the science, since in this way the cabbage and hemlock afforded the same products.

It is clear that an analysis by the retort ought not to shew the principles of vegetation: for, not to mention that heat changes their nature by becoming a constituent part of the



principles extracted; these principles themselves become mixed together, and we can never know their order or state while in the living plant. The action of the heat moreover causes the vegetable principles to react upon each other, and confounds the whole together. Whence it arises that all vegetables afford nearly the same principles; namely, water, an oil more or less thick, an acid liquor, a concrete salt, and a coal or caput mortuum more or less abundant.

Hales took notice that the distillation of vegetables afforded much air; and was even in possession of an apparatus to collect and measure it. But in our time the methods of collecting and confining the gases are simplified; and the hydro-pneumatic apparatus has proved that the substances are formed of a mixture of carbonic acid, hydrogen, and sometimes a little nitrogen.

The order in which the several products are obtained, and the characters they exhibit, lead us to the following observations:

1. The water which passes first is usually pure, and without smell; but when odorant plants are distilled, the first drops are impregnated with their aroma. These first portions of water consist of that which was superabundant, and impregnated the vegetable tissue. When the water of composition, or that which was in combination with the vegetable, begins to rise, it carries along with it a small quantity of oil, which colours it; and some portions of a weak acid, afforded by the mucilage and other principles with which it existed in the saponaceous state. The phlegm likewise very often contains a small quantity of ammoniac: and this alkali appears to be formed in the operation itself; for there are few plants which contain it in their natural state.

2. To the phlegm succeeds an oily principle, little coloured at first; but in proportion as the distillation advances, the oil which rises is thicker, and more coloured. They are all characterized by a smell of burning, and an acrid taste, that arise from the impression of the fire itself. These oils are most of them resinous, and the nitric acid easily inflames them. They may be rendered more fluid and volatile by repeated distillations.

3. In proportion as the oil comes over, there sometimes distills carbonate of ammoniac, which attaches itself to the sides of the vessels. It is usually soiled with an oil which colours it. This salt does not appear to exist ready formed in vegetables. Rouelle the younger proved that the plants which afford the most of it, such as the cruciferous plants, do not contain it in their natural state. It is therefore found when its component parts are volatilized and reunited by the distillation.

4. All vegetables afford a very great quantity of gas by distillation; and their nature has an influence on the gaseous substances they afford. Those plants which abound with resin, afford much more hydrogenous gas; while such as abound with mucilage produce carbonic acid.

The mixture of these gases forms an air which is heavier than the common inflammable air, on which account it has been found very little adapted to aërostatic experiments.

The art of charring wood, or converting it into charcoal, is an operation nearly similar to the distillation we have just described. It consists in forming pyramids of wood, or cones truncated at their summit. The whole is covered with earth, well beaten, leaving a lower and upper aperture. The mass is then set on fire; and when the whole is well ignited, the combustion is stopped by closing the apertures through which the current of air passed. By this means the water, the oil, and all the principles of the vegetable, are dissipated, except the fibre. The wood in this operation loses three-fourths of its weight, and one-fourth of its bulk. According to Fontana and Morozzo, it absorbs air and water as it cools. I am assured, from my experiments in the large way, that pit-coal desulphurated (coaked) acquires twenty-five pounds of water in the quintal by cooling; but the coal of wood did not appear to me to absorb more than fifteen or twenty. The futurbrand of the Icelanders is nothing but wood converted into charcoal by the lava which has surrounded it.—See Von Troil's Letters on Iceland.

The charcoal which is the residue of all these distillations, is a substance which deserves an attention more particularly because it enters into the composition of many bodies, and bears a very great part in their phenomena.

Charcoal is the vegetable fibre very slightly changed. It most commonly preserves the form of the vegetable which afforded it. The primitive texture is not only distinguishable, but serves likewise to indicate the state and nature of the vegetable which has afforded it. It is sometimes hard, sonorous, and brittle; sometimes light, spongy, and friable; and some substances afford it in a subtle powder, without consistence. The coal of oils and resins is of this nature.

Charcoal well made has neither smell nor taste; and it is one of the most indecomposable substances we are acquainted with.

When dry, it is not changed by distillation in close vessels. But, when moist, it affords hydrogenous gas and carbonic acid; which proves the decomposition of the water, and the combination of one of its principles with the charcoal, while the other is dissipated. By successively moistening and distilling charcoal, it may be totally destroyed.

Charcoal combines with oxigene, and forms the carbonic acid; but this combination does not take place unless their action be assisted by heat. The charcoal which burns in a chaffing-dish exhibits this result; and we perceive two very immediate effects in this operation:—1. A disengagement of heat, afforded by the transition of the oxigenous gas to the concrete state. 2. A production of carbonic acid: it is the formation of this acid gas which renders it dangerous to burn charcoal in places where the current of air is not sufficiently rapid to carry off the carbonic acid as it is formed.

Well-made charcoal does not change by boiling in water. In process of time it gives a slight reddish tinge to that fluid, which arises from the solution of the coaly residue of the oils of the vegetable mixed with the coaly residue of the fibre.

If the sulphuric acid be digested upon charcoal, it is decomposed; and affords carbonic acid, sulphureous acid, and sulphur.

The nitric acid, when concentrated, is decomposed with much greater rapidity; for if it be poured upon very dry powder of charcoal, it sets it on fire. This inflammation may be facilitated by heating the charcoal or the acid. If the fluid which arises in this experiment be collected, it is found to be carbonic acid, nitrous gas, and nitric acid. M. Proust has observed, that when the acid is poured into the

middle of the charcoal, it does not take fire; but that this effect immediately succeeds if the acid be suffered to flow beneath the coal. It may even be inflamed by throwing it upon the nitric acid slightly heated.

If weak nitric acid be digested upon charcoal, it dissolves it, assumes a red colour, becomes pasty, and acquires a bitter disagreeable taste.

Charcoal, mixed with the sulphuric and nitric salts, decomposes them; when combined with oxides, it revives the metals. All these effects depend on its very great affinity with the oxigene contained in these bodies. It is used to facilitate the decomposition of salt-petre in some cases, as in the composition of gun-powder, the black flux, &c.

Rouelle has observed that the fixed alkali dissolves a good quantity of charcoal by fusion. The same chemist has discovered that the sulphure of alkali dissolves it in the humid as well as the dry way.

Charcoal is likewise capable of combining with metals. It combines with iron in its first fusion, and mixes with it likewise in the cementation by which steel is formed. When combined with iron in a small proportion of the metal, it constitutes plumbago. It is likewise capable of combining with tin by cementation; to which metal it gives brilliancy and hardness, as I find by experiment.

## CHAP. II.

Concerning the Action of Water singly applied to Vegetables.

WE may consider the action of water upon vegetables in two very different points of view. Either the chemist applies this fluid to the plant itself, to extract and separate the juices from the ligneous part: or else the plant itself, being immersed in this fluid, is from this time delivered to its single action; and in that situation becomes gradually changed and decomposed in a peculiar manner. In these two cases, the products of the operations are very different. In the first, the ligneous texture remains untouched, and the juices which are separated remain unchanged in the



fluid: in the second, more especially when vegetables ferment in heaps, the nature of the juices is partly changed, but the oils and resins remain confounded with the ligneous tissue; so that the result is a mass in which the disorganized vegetable is seen in a state of mixture and confusion of the various principles which compose it.

The chemist applies water to vegetables, to extract their juices, according to two methods, which constitute infusion and decoction.

Infusion is performed by pouring upon a vegetable a sufficient quantity of hot water to dissolve all its principles. The temperature of the water must be varied according to the nature of the plant. If its texture be delicate, or the aroma very fugacious, the water must be slightly heated; but boiling water may be used when the texture is hard and solid, and more especially when the plant has no smell.

Decoction, which consists in boiling water with the vegetable, ought not to be employed but with hard and inodorous plants. This method is rejected by many chemists; because they affirm that, by thus tormenting the plant, a considerable quantity of fibrous matter becomes mixed with the juices. Decoction is generally banished from the treatment of odorant plants, because it dissipates the volatile oil and aroma. The decoction used in our kitchens to prepare leguminous plants for food, has the inconvenience of extracting all the nutritive parts, and leaving only the fibrous parenchyma. Hence arises the advantage of the American pot or boiler, in which the garden-stuff is boiled by simple vapour, and consequently the nutritive principle remains in the vegetable; to which advantage we may add that of using any water whatever, because the steam alone is applied to the intended purpose.

But the infusion, decoction, and clarification of juices, is not left to the choice of the chemist, when it is required to prepare any medicine; for these methods produce surprising varieties in the virtue of remedies. Thus, for example, according to Storck, the concentrated juice of hemlock has no good qualities unless it be evaporated without being clarified.

In treating juniper berries by infusion, and evaporation on a water bath to the consistence of honey, an aromatic extract is obtained, of a saccharine colour: the decoction of the

same berries affords a less fragrant and less resinous extract, because the resin separates from the oil, and falls down.

The extract of grapes, which is called *refiné* in France, and most sweetmeats, are prepared in this way.

Extracts are prepared in the large way for sale by the assistance of water. We shall confine ourselves to speak of two only, the juice of liquorice and of cachou. The first will afford an example of decoction, and the second of infusion.

The extract of liquorice is prepared in Spain by decoction of the shrub of the same name. This plant grows abundantly near our ponds; and we might at a small expence avail ourselves of this species of industry: I have ascertained that a pound of this root affords two or three ounces of good extract. The apothecaries afterwards prepare it in various ways for their several purposes, and to render its use more convenient and agreeable.

The cachou is extracted in the East-Indies from an infusion of the seeds of a kind of palm. While the seed is yet green, it is cut, infused in hot water; and this infusion is evaporated to the consistence of an extract, which is afterwards made into lumps, and dried in the sun. M. de Jussieu communicated to the Academy, in the year 1720, remarks by which he ascertains that the differences in the several kinds of cachou arise from the various degrees of maturity in the seeds, and the greater or less quickness with which the extract is dried.

The cachou of commerce is usually impure; but it may be cleared of its impurities by dissolving, filtering, and evaporating it several times.

The taste of cachou is bitter and astringent. It dissolves very well in the mouth, and is used as a restorative for weak stomachs: it is made into comfits by the addition of three parts of sugar, and a sufficient quantity of gum adragant.

When vegetables are immersed in water, their texture becomes relaxed; all the soluble principles are carried off; and there remains only the fibrous part disorganized, and impregnated with vegetable oil, altered and hardened by the reaction of other principles. This transition may be very well observed in marshes, where plants grow and perish in great numbers, forming mud by their decomposition.

These strata of decomposed vegetables, when taken out of the water and dried, may be used as the material of combustion. The smell is unwholesome; but in shops, or places where the chimneys draw well, this combustible may be used.

Vegetables have been considered as the cause of the formation of pit-coal; but a few forests being buried in the earth, are not sufficient to form the mountains of coal which exist in its bowels. A greater cause, more proportioned to the magnitude of the effect, is required; and we find it only in that prodigious quantity of vegetables which grow in the seas, and is still increased by the immense mass of those which are carried down by rivers. These vegetables, carried away by the currents, are agitated, heaped together, and broken by the waves; and afterwards become covered with strata of argillaceous or calcareous earth, and are decomposed. It is easier to conceive how these masses of vegetables may form strata of coal, than that the remains of shells should form the greater part of the globe.

The direct proofs which may be given of the truth of this theory are—

1. The presence of vegetables in coal mines. The bamboo and bannana trees are found in the coal of Alais. It is common to find terrestrial vegetables confounded with marine plants.

2. The prints of shells and of fish are likewise found in the strata of coal, and not unfrequently shells themselves. The pit-coal of Orsan and that of Saint-Esprit contain a prodigious number.

3. It is evidently seen, by the nature of the mountains which contain charcoal, that their formation has been submarine; for they all consist either of schistus, or grit, or limestone. The secondary schistus is a kind of coal in which the earthy principle predominates over the bituminous. Sometimes even this schistus is combustible, as is seen in that of St. George near Milhaud. The texture of the vegetables, and the impression of fish, are very well preserved in the schistus. The origin of the schistus is therefore submarine; and consequently so likewise must be the origin of the coal distributed in strata through its thickness.

The grit-stone consists of sand heaped together, carried into the sea by the rivers, and thrown up against the shores

by the waves. The strata of bitumen which are found in these cannot therefore but come from the sea.

Calcareous earth rarely contains strata of coal, but is merely impregnated with it, as at St. Ambroise, at Servas, &c. where the bitumen forms a cement with the calcareous earth.

#### Concerning Pit-Coal.

Pit-coal is usually found in strata in the earth, almost always in mountains of schistus or grit. It is the property of coal to burn with flame, and the emission of much smoke.

The secondary schistus is the basis of all pit-coal, and the quality of the coal mostly depends upon the proportion of this basis. When the schistus predominates, the coal is heavy, and leaves a very abundant earthy residue after its combustion. This kind of coal is veined internally with flat pieces, or rather separate masses, of schistus nearly pure, which we call *fiches*.

As the formation of the pyrites, as well as that of coal, arises from the decomposition of vegetable and animal substances, all pit-coal is more or less pyritous; so that we may consider pit-coal as a mixture of pyrites, schistus, and bitumen. The different qualities of coal arise therefore from the difference in the proportions of these principles.

When the pyrites is very abundant, the coal exhibits yellow veins of the mineral, which are decomposed as soon as they come in contact with the air; and form an efflorescence of sulphate of magnesia, of iron, of alumine, &c.

When pyritous coal is set on fire, it emits an insupportable smell of sulphur; but when the combustion is insensible, inflammation is frequently produced by the decomposition of the pyrites; and it is this which occasions the inflammation of several veins of coal. There are veins of coal on fire at St. Etienne in Forez, at Cramfac in Rouergue, at Requecremade in the diocese of Beziers; and it is not rare to see the fire destroy considerable masses of pyritous coal, when the decomposition is favoured by the concurrence of air and water. If the inflammation be excited in more considerable masses of bitumen, the effects are then more striking; and it is to a cause of this nature that we ought to refer the origin and effect of volcanoes.



When the schistus, or stony principle, predominates in coals, they are then of a bad quality, because their earthy residue is more considerable.

The best coal is that in which the bituminous principle is the most abundant, and exempt from all impurity. This coal sweels up when it burns, and the fragments adhere together: it is more particularly upon this quality that the practice of the operation called desulphurating or purifying of coal depends. This operation is analogous to that in which wood is converted into charcoal. In the desulphuration, pyramids are made, which are set on fire at the centre. When the heat has strongly penetrated the mass, and the flame issues out of the sides, it is then covered with moist earth; the combustion is suffocated, the bitumen is dissipated in smoke, and there remains only a light spongy coal, which attracts the air and humidity, and exhibits the same phenomena in its combustion as the coal of wood. When it is well made, it gives neither flame nor smoke; but it produces a stronger heat than that of an equal mass of native coal. This operation received the name of desulphurating (*desoufrage*) from a notion that the coal was by this means deprived of its sulphur; but it has been proved that all coals which are capable of this operation, contain scarcely any sulphur.

It was for a long time supposed that the smell of pit-coal was unwholesome; but the contrary is now proved. Mr. Venel has made many experiments on this subject, and is convinced that neither man nor animals are incommoded by this vapour. Mr. Hoffman relates that disorders of the lungs are unknown in the villages of Germany, where this combustible only is used. I think that coal of a good quality does not emit any dangerous vapour; but when it is pyritous its smell cannot but be hurtful.

The use of coal is generally applicable to the arts; and nature appears to have concealed these magazines of combustible matter, to give us time to repair our exhausted forests. These mines are very abundant and numerous in the kingdom of France. Our province contains many; and we have more than twenty which are in full work. Pit-coal is applied in England even to domestic uses, and this part of mineralogy is very much cultivated in that kingdom. Individuals have there undertaken the most considerable enterprizes in

this way. The Duke of Bridgewater has made a canal, at Bridgewater, two thousand five hundred toises in length, to facilitate the working of the coal mines in Lancashire. It cost five million of livres: part of it is carried under a mountain; and it passes successively under as well as over rivers and highways. In our province we are in want of roads only for the transportation of our coal; and Languedoc has not had the spirit to perform a work which a private individual has executed in England.

In Scotland, Lord Dundonald has erected furnaces in which the bitumen is disengaged from coal; and the vapours are received and condensed in chambers, over which he has caused a river to flow for the purpose of cooling them. These condensed vapours supply the English navy with as much tar as it requires. Becher, in his work intitled "Foolish Wisdom, or Wise Folly," printed at Franckfort in 1683, affirms that he succeeded in appropriating the bad turf of Holland, and the bad coal of England, to the common uses. He adds that he obtained tar superior to that of Sweden by a process similar to that of the Swedes. He affirms that he had made this known in England, and shewn it to the King.

Mr. Faujas has carried the process of the Scotch nobleman into execution at Paris. The whole consists in setting fire to the coal, and extinguishing it at the proper time, that the vapour may pass into chambers containing water for the purpose of condensing them. This tar appeared to be superior to that of wood.

Pit-coal likewise affords ammoniac by distillation, which is dissolved in water, while the oil floats above.

When coal is deprived by combustion of all the oil and other volatile principles, the earthy residue contains the sulphates of alumine, iron, magnesia, lime, &c. These salts are all formed when the combustion is slow; but when it is rapid the sulphur is dissipated, and there remain only the aluminous, magnesian, calcareous, and other earths. The alumine most commonly predominates.

Naptha, petroleum, mineral pitch, and asphalt, are only slight modifications of the bituminous oil so abundant in pit-coal. This oil, which the simple heat of the decomposition of the pyrites is sufficient to disengage from the coal, receives other modifications by the impression of the external air.

Petroleum, or the oil petrol, is the first alteration. This oil is found near volcanos, in the vicinity of coal mines, &c. We are acquainted with several springs of this petroleum. There is one at Gabian in the diocese of Beziers. It is carried out by the water of a spring which issues from the lower part of a mountain whose summit is volcanized.

The smell of petroleum is disagreeable: its colour is reddish; but it may be rendered clear by distilling it from the clay of Murviel.

Naptha is merely a variety of petroleum.

Near Derbens, on the Caspian Sea, there are springs of naptha, which Kempfer visited about a century ago, and of which he has left a description.

There is a place known by the name of the Perpetual Fire, where the fire burns without ceasing. The Indians do not attribute the origin of this inextinguishable fire to naptha; but they maintain that God has confined the Devil in this place, to deliver man from him. They go in pilgrimage thither, and make their prayers to God that he will not suffer this enemy of mankind to escape.

The earth impregnated with naptha is calcareous, and effervesces with acids; it takes fire by the contact of any ignited body whatever.

This perpetual fire is of great use to the inhabitants of Baku. They pare off the surface of this burning soil, upon which they make a heap of limestones, and cover it with the earth pared off; and in two or three days the lime is made.

The inhabitants of the village of Frogann repair to this place to cook their provisions.

The Indians assemble from all parts to adore the Eternal Being in this place. Several temples were built, one of which is still in existence. Near the altar there is a tube inserted in the earth, two or three feet in length; out of which issues a blue flame, mixed with red. The Indians prostrate themselves before this tube, and put themselves into attitudes which are exceedingly strange and painful.

Mr. Gmelin observes that two kinds of naptha are distinguished in this country; the one transparent and yellow, which is found in a well. This well is covered with stones smeared with a cement of fat earth, in which the name of



Kan is engraved; and no one is permitted to break this sealed covering but those who are deputed from the Kan.

Mineral pitch is likewise a modification of petroleum. It is found in Auvergne, at a place called Puits de Lapege, near Allais, in an extent of several leagues, which comprehends Servas, Saint Ambroix, &c.

The calcareous stone is impregnated with a bitumen which is softened by the heat of summer, when it flows from the rocks, and forms a very beautiful stalactites. It forms masses in the fields, and impedes the passage of carriages: the peasants use it to mark their sheep. This stone emits an abominable smell when rubbed. The episcopal palace of Alais was paved with it in the time of Mr. Davejan; but it became necessary to substitute other stone in its stead. It is asserted that mineral pitch was used to cement the walls of Babylon.

Asphaltes, or bitumen Judaicum, is black, brilliant, ponderous, and very brittle.

It emits a smell by friction; and is found floating on the water of the lake Asphaltites, or the Dead Sea.

The asphaltes of commerce is extracted from the mines of Annemore, and more particularly in the principality of Neufchatel. Mr. Pallas found springs of asphaltes on the banks of the Sock, in Prussia.

Most naturalists consider it as amber decomposed by fire.

Asphaltes liquefies on the fire, swells up, and affords flame, with an acrid disagreeable smoke.

By distillation it affords an oil resembling petroleum. The Indians and Arabs use it instead of tar, and it is a component part of the varnish of the Chinese.

Yellow amber, karabe, or the electron of the ancients, is in yellow or brown pieces, transparent or opaque, capable of a polish, becoming electric by friction, &c.

It is friable and brittle.

There is no substance on which the imagination of poets has been more exercised than this. Sophocles had affirmed that it was formed in India by the tears of the sisters of Meleager, changed into birds, and deploring the fate of their brother; but one of the most interesting fabulous origins which have been attributed to it, is afforded by the fable of Phaeton burning the heavens and the earth, and precipitated by the thunder of Jove into the waters of Eridanus. His



filters are described weeping; and the precious tears fell into the waters without mixing with them, became solid without losing their transparency, and were converted into the yellow amber so highly valued by the ancients.—See Bailly.

Amber possesses less coaly matter than any other bitumen.

It is frequently found dispersed over strata of pyritous earth, and covered with a stratum of wood, abounding with a blackish bituminous matter.

It is found floating in the Baltic Sea, on the coast of Ducal Prussia; it is also found near Sistreron in Provence.

No other chemical use was for a long time made of amber, than to form compositions for medicine and the arts. We are indebted to Neumann, Bourdelin, and Pott for a tolerably accurate analysis of this bitumen. The two constituent principles exhibited in the analysis of amber, are the salt of amber, or succinic acid, and a bituminous oil.

To extract the succinic acid, the amber is broken into small pieces, which are put into a retort, and distilled with a suitable apparatus upon a sand bath. When the fire is carefully managed, the products are—1. An insipid phlegm. 2. Phlegm holding a small portion of acid in solution. 3. A concrete acid salt, which attaches itself to the neck of the retort. 4. A brown and thick oil, which has an acid smell.

The concrete salt always retains a portion of oil\* in its first distillation. Scheffer, in his *Lessons of Chemistry*, proposes to distil it with sand; Bergmann with white clay; Pott advises solution in water, and filtration through white cotton; after which the fluid is to be evaporated, and is found to be deprived of the oil, which remains on the cotton. Spielmann, after Pott, proposes to distil it with the muriatic acid; it then sublimes white and pure. Bourdelin clears it of its oil by detonation with nitre. This salt is prepared in the large way at Königsberg, where the shavings and chips of amber are distilled.

The succinic acid has a penetrating taste, and reddens the tincture of turnsole. Twenty-four parts of cold water, and two of boiling water, dissolve one of this acid. If a saturated solution of this salt be evaporated, it crystallizes in triangular prisms, whose points are truncated.

\* *Acide* in the original: doubtless by oversight. T.

Mr. De Morveau observes that its affinities are barytes, lime, alkalis, magnesia, &c.

The oil of amber has an agreeable smell: it may be deprived of its colour by distillation from white clay. Rouelle distilled it with water. When mixed with ammoniac it forms a liquid soap, known by the name of Eau de Luce.

To make eau de luce, I dissolve Punic wax in alcohol, with a small quantity of oil of amber; and on this I pour the pure volatile alkali.

Alcohol attacks amber, and acquires a yellow colour. Hoffmann prepares this tincture by mixing the spirit of wine with an alkali.

The medical use of amber consists in burning it, and receiving the vapour on the diseased part. These vapours are strengthening, and remove obstructions. The oil of amber is applied to the same use. A syrup of amber is made with the spirit of amber and opium, which is used to advantage as a sedative anodyne medicine. The finest pieces of amber are used to make toys. Wallerius affirms that the most transparent pieces may be used to make mirrors, prisms, &c. It is said that the King of Prussia has a burning mirror\* of amber one foot in diameter; and that there is a column of amber in the cabinet of the Duke of Florence ten feet high, and of a very fine lustre.

#### Concerning Volcanos.

The combustion of those enormous masses of bitumen which are deposited in the bowels of the earth, produces volcanos. They owe their origin more especially to the strata of pyritous coal. The decomposition of water upon the pyrites determines the heat, and the production of a great quantity of hydrogenous gas, which exerts itself against the surrounding obstacles, and at length breaks them. This effect is the chief cause of earthquakes; but when the concurrence of air facilitates the combustion of the bitumen and the hydrogenous gas, the flame is seen to issue out of the chimneys or vents which are made: and this occasions the fire of volcanos.

\* So in the original; but the matter as well as the properties of this substance put it out of doubt that it should be *lens*. T.

There are many volcanos still in an active state on our globe, independent of those of Italy, which are the most known. The abbé Chappe has described three burning in Siberia. Anderson and Von Troil have described those of Iceland. Asia and Africa contain several: and we find the remains of these fires or volcanic products in all parts of the globe.

Naturalists inform us that all the southern islands have been volcanized; and they are seen daily to be formed by the action of these subterraneous fires. The traces of fire exist even immediately around us. The single province of Languedoc contains more extinct volcanos than twenty years ago were known to exist through all Europe. The black colour of the stones, their spongy texture, the other products of fire, and the identity of these substances with those of the volcanos at present burning, are all in favour of the opinion that their origin was the same\*.

\* A volcano was announced and described to be burning in Languedoc, respecting which it is necessary to give some elucidation. This pretended volcano is known by the name of the Phosphorus of Venejan.

Venejan is a village situated at the distance of a quarter of a league from the high road between St. Esprit and Bagnols. From time immemorial, at the return of spring, a fire was seen from the high road, which increased during the summer, was gradually extinguished in autumn, and was visible only in the night. Several persons had at various times directed their course from the high road, in a right line towards Venejan, to verify the fact upon the spot: but the necessity of descending into a deep valley before they could arrive thither, occasioned them to lose sight of the fire; and on their arrival at Venejan no appearance was seen in the least resembling the fire of a volcano. Mr. de Genfane describes this phenomenon, and compares it to the flashing of a strong aurora borealis: he even says that the country is volcanic. *Hist. Nat. du Languedoc, Diocèse de Uzès.*—At length, in the course of the last four or five years, it was observed that these fires were multiplied in the spring; and that, instead of one, there were three. Certain philosophers of Bagnols undertook the project of examining this phenomenon more closely; and for this purpose they repaired to a spot between the high road and Venejan, armed with torches, speaking trumpets, and every other implement which they conceived to be necessary for making their observations. At midnight, four or five of the party were deputed and directed towards the fire; and those who remained behind directed them constantly in their way by means of their speaking trumpets. They at last arrived at the village, where they found three groupes of women winding silk in the middle of the street by the light of a fire made of hemp stalks. All the volcanic phenomena then disappeared, and the explanation of the observations made on this subject became very simple. In the spring, the fire was weak, because it was fed with wood, which afforded heat and light; during the summer, hemp stalks were burned, because light only was wanted. At that time there were three fires, because the fair of Saint Esprit



When the decomposition of the pyrites is advanced, and the vapours and elastic fluids can no longer be contained in the bowels of the earth, the ground is shaken, and exhibits the phenomena of earthquakes. Mephitic vapours are multiplied on the surface of the ground, and dreadful hollow noises are heard. In Iceland, the rivers and springs are swallowed up: a thick smoke, mixed with sparks and lightning, is then disengaged from the crater; and naturalists have observed that, when the smoke of Vesuvius takes the form of a pine, the eruption is near at hand.

To these preludes, which shew the internal agitation to be great, and that obstacles oppose the issue of the volcanic matters, succeeds an eruption of stones and other products, which the lava drives before it; and lastly appears a river of lava, which flows out, and spreads itself down the side of the mountain. At this period the calm is restored in the bowels of the earth, and the eruption continues without earthquakes. The violent efforts of the included matter sometimes cause the sides of the mountain to open; and this is the cause which has successively formed the smaller mountains which surround volcanos. Montenuovo, which is a hundred and eighty feet high, and three thousand in breadth, was formed in a night.

This crisis is sometimes succeeded by an eruption of ashes which darken the air. These ashes are the last result of the alteration of the coals; and the matter which is first thrown out is that which the heat has half vitrified. In the year 1767, the ashes of Vesuvius were carried twenty leagues out to sea, and the streets of Naples were covered with them. The report of Dion, concerning the eruption of Vesuvius in the reign of Titus, wherein the ashes were carried into Africa, Egypt, and Syria, seems to be fabulous. Mr. de Saussure observes that the soil of Rome is of this character, and that the famous catacombs are all made in the volcanic ashes.

It must be admitted, however, that the force with which all these products are thrown, is astonishing. In the year 1708, when the silk-throwers were at work, and which consequently put them under the necessity of expediting their work. As these observers announced their arrival with much noise, the country people drove them back by a shower of stones which the Dop Quixotes of natural history might have taken for a volcanic eruption.



1769, a stone twelve feet high, and four in circumference, was thrown to the distance of a quarter of a mile from the crater: and in the year 1771, Sir William Hamilton observed stones of an enormous size, which employed eleven seconds in falling.

The eruption of volcanos is frequently aqueous: the water, which is confined, and favours the decomposition of the pyrites, is sometimes strongly thrown out. Sea salt is found among the ejected matter, and likewise sal ammoniac. In the year 1630, a torrent of boiling water, mixed with lava, destroyed Portici and Torre del Greco. Hamilton saw boiling water ejected. The springs of boiling water in Iceland, and all the hot springs which abound at the surface of the globe, owe their heat only to the decomposition of pyrites.

Some eruptions are of a muddy substance; and these form the tufa, and the puzzolano. The eruption which buried Herculaneum is of this kind. Hamilton found an antique head, whose impression was well enough preserved to answer the purpose of a mould. Herculaneum, at the least depth is seventy feet under the surface of the ground, and often at one hundred and twenty.

The puzzolano is of various colours. It is usually reddish; sometimes grey, white, or green: it frequently consists of pumice stone in powder; but sometimes it is formed of calcined clay. One hundred parts of red puzzolano afforded Bergman, silica 55, alumina 20, lime 5, iron 20.

When the lava is once thrown out of the crater, it rolls in large rivers down the side of the mountain to a certain distance, which forms the currents of lava, the volcanic causeways, &c. The surface of the lava cools, and forms a solid crust, under which the liquid lava flows. After the eruption, this crust sometimes remains, and forms hollow galleries, which Messrs. Hamilton and Ferber have visited: it is in these hollow places that the sal ammoniac, the marine salt, and other substances, sublime. A lava may be turned out of its course by opposing banks or dikes against it: this was done in 1669, to save Catania; and Sir William Hamilton proposed it to the king of Naples, to preserve Portici.

The currents of lava sometimes remain several years in cooling. Sir William Hamilton observed, in 1769, that the lava which flowed in 1766 was still smoking in some places.

When the current of lava is received by water, its cooling is quicker; and the mass of lava shrinks so as to become divided into those columns which are called basaltcs. The famous Giants Causeway is the most astonishing effect of this kind which we are acquainted with. It exhibits thirty thousand columns in front, and is two leagues in length along the sea coast. These columns are between fifteen and sixteen inches in diameter, and from twenty-five to thirty feet long.

The basaltcs are divided into columns of four, five, six, and seven sides. The emperor Vespasian made an entire statue, with sixteen children, out of a single column of basaltcs, which he dedicated to the Nile, in the temple of Peace.

Basaltcs afforded Bergman, per quintal, silicx 56, aluminc 15, lime 4, iron 25.

Lava is sometimes swelled up and porous. The lightest is called pumice-stone.

The substances thrown out by volcanos are not altered by fire. They eject native substances, such as quartz, crystals of amethyst, agate, gypsum, amianthus, feld-spar, mica, shells, schorl, &c.

The fire of volcanos is seldom strong enough to vitrify the matters it throws out. We know only of the yellowish capillary and flexible glass thrown out by the volcanos of the island of Bourbon on the fourteenth of May 1766 (M. Commerçon), and the lapis gallinaceus ejected by Hecla. Mr. Ego-frjouson, who is employed by the Observatory at Copenhagen, has settled in Iceland, where he uses a mirror of a telescope which he has made out of the black agate of Iceland.

The slow operation of time decomposes lavas, and their remains are very proper for vegetation. The fertile island of Sicily has been every where volcanized. I observed several ancient volcanos at present cultivated; and the line which separates the other earths from the volcanic earth, constitutes the limit of vegetation. The ground over the ruins of Pompeia is highly cultivated. Sir William Hamilton considers subterranean fires as the great vehicle used by nature to extract virgin earth out of the bowels of the globe, and repair the exhausted surface.

The decomposition of lava is very slow. Strata of vegetable earth, and pure lava, are occasionally found applied

one over the other; which denote eruptions made at distances of time very remote from each other, since it requires nearly two thousand years before lava receives the plough. An argument has been drawn from this phenomenon to prove the antiquity of the globe: but the silence of the most ancient authors concerning the volcanos of our kingdom, of which we find such frequent traces, proves that these volcanos have been extinguished from time immemorial; a circumstance which carries their existence to a very distant period. Besides this, several thousand years of connected observations have not afforded any remarkable change in Vesuvius or Etna; nevertheless, these enormous mountains are all volcanized, and consequently formed of strata applied one upon the other. The prodigy becomes much more striking, when we observe that all the surrounding country, to very great distances, has been thrown out of the bowels of the earth.

The height of Vesuvius above the level of the sea is three thousand six hundred and fifty-nine feet; its circumference thirty-four thousand four hundred and forty-four. The height of Etna is ten thousand and thirty-six feet; and its circumference one hundred and eighty thousand.

The various volcanic products are applicable to several uses.

1. The puzzolano is of admirable use for building in the water: when mixed with lime, it speedily fixes itself; and water does not soften it, for it becomes continually harder and harder. I have proved that calcined ochres afford the same advantage for this purpose; they are made into balls, and baked in a potter's furnace in the usual manner. The experiments made at Sette, by the commissary of the province, prove that they may be substituted with the greatest advantage, instead of the puzzolano of Italy.

2. Lava is likewise susceptible of vitrification; and in this state it may be blown into opaque bottles of the greatest lightness, as I have done at Erepian and at Alais. The very hard lava, mixed in equal parts with wood ashes and soda, produced an excellent green glass. The bottles made of it were only half the weight of common bottles, and much stronger; as was proved by my experiments, and those which Mr. Jolly de Fleury ordered to be made under his administration.



3. Pumice stone likewise has its uses; it is more especially used to polish most bodies which are somewhat hard. It is employed in the mass or in powder, according to the intended purpose. Sometimes, after levigation, it is mixed with water to render it softer.

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### CHAPTER III.

Concerning the Decomposition of Vegetables in the Bowels of the Earth.

**H**ERBACEOUS plants, buried in the earth, are slowly decomposed; but the waters which filter through and penetrate them relax their texture. The salts are extracted; and they become converted into a stratum of blackish matter, in which the vegetable texture is still discernible. These strata are sometimes perceived in digging into the earth. But this alteration is infinitely more perceptible in wood itself, than in herbaceous plants. The ligneous body of a tree buried under the ground becomes of a black colour, more friable, and breaks short; the fracture is shining; and the whole mass appears, in this state, to form an uniform substance, capable of the finest polish. The wood thus changed is called Jet. In the environs of Montpellier, near St. Jean de Cucule, several cart loads of trunks of trees have been dug up, whose form was perfectly preserved, but which were converted into jet. I have myself found a wooden peal converted into jet. In the works at Nîmes pieces of wood were found entirely converted into the state of jet. In the neighbourhood of Vachery, in Gevaudan, a jet is found, in which the texture of the walnut tree is very discernible. The texture of the beech is seen in the jet of Bosrup in Scania. In Guelbre a forest of pines has been discovered buried beneath the sand; and at Beichlitz two strata of coal are wrought, according to Mr. Jars, the one bituminous, and the other of fossil wood. I preserve in the cabinet of mineralogy of Languedoc, several pieces of wood whose external part is in the state of jet, while the internal part still remains in the ligneous state; so that the transition from the one to the other may be observed.

Jet is capable of receiving the most perfect polish. It is made into toys, such as buttons, snuff-boxes, necklaces, and other ornaments. It is wrought in Languedoc, near Saint-



Colombe, at the distance of three leagues from Castelnau-dray. It is ground down, and cut into facets, by mills.

Jet softens in the fire, and burns with the emission of a fetid odour. It affords an oil which is more or less black, but may be rendered colourless by repeated distillations from the earth of Murviel.

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#### CHAPTER IV.

Concerning the Action of Air and Heat upon Vegetables.

**W**HEN the heat is applied to a vegetable exposed to the air, certain phenomena are produced, which depend on the combination of pure air with the inflammable principles of the plant; and this is combustion.

In order to produce a commencement, a heated body is applied to the dry wood which is intended to be set on fire. By this means the principles are volatilized in the same order as we have pointed out in the preceding article. A smoke is produced, which is a mixture of water, oil, volatile salts, and all the gaseous products which result from the combination of vital air with the several principles of the vegetable. The heat then increases by the combination of the air itself, because it passes to the concrete state: and when this heat is carried to a certain point, the vegetable takes fire, and the combustion proceeds until all the inflammable principles are destroyed.

In this operation there is an absorption of vital air, and a production of heat and light. The combustion will be stronger in proportion as the inflammable principle is more abundant, as the aqueous principle is less abundant, as the wood is more resinous, and as the air is purer and more condensed.

The disengagement of heat and light is more considerable, accordingly as the combination of vital air is stronger in a given time.

The residues of combustion consist of substances which are volatilized, and fixed substances; the one forms the foot, the other the ashes.

The foot partly arises from substances imperfectly burned, decomposed only in part, which have escaped the action of

vital air. Hence it is that the foot may be burned over again: and hence likewise it is that, when the combustion is very rapid and effectual, there is no perceptible smoke; because all the inflammable matter is then destroyed, as in the cylinder lamps, violent fires, &c.

The analysis of foot exhibits an oil which may be extracted by distillation; a resin which may be taken up by alcohol, and which arises either from the imperfect alteration of the resin of the vegetable, or the combination of vital air with the volatile oil. It likewise affords an acid, which is often formed by the decomposition of mucus; and it is this acid, of great utility in the arts, for which the Academy of Stockholm has described a furnace proper for collecting it. Soot likewise affords volatile salts, such as the carbonate of ammoniac, and others. A slight portion of fibrous matter is likewise volatilized by the force of the fire, and we find it again in the foot.

The fixed principle remaining after combustion, forms the ashes. They contain salts, earths, and metals, of which we have already treated. The salts are fixed alkalis, sulphates, nitrates, muricates, &c. the metals are iron, gold, manganese, &c. and the earths are alumine, lime, silica, and magnesia.

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## CHAPTER V.

Concerning the Action of Air and Water, which determine a Commencement of Fermentation that separates the Vegetable Juices from the Ligneous Part.

WHEN the decomposition of vegetables is facilitated by the alternate action of air and water, their organization becomes destroyed; the connection between the various principles is broken; the water carries away the juices; and leaves the fibrous skeleton naked, sufficiently coherent, and sufficiently abundant in certain vegetables, to be extracted in this way. Hemp is prepared in this manner. The abbé Rozier attributes the advantage of watering to the fermentation of the mucilaginous part. M. Prozet has proved that hemp contains an extractive and resinous part; and that the watering destroys the former, and the second is detached

almost mechanically. It has been observed that the addition of a small quantity of alkali favours this operation.

Running water is preferable to standing water; because standing water keeps up and developes a stronger fermentation, which attacks the ligneous part. It has been observed that flax prepared in running water is whiter and stronger than that which is prepared in standing water. The stagnant water has likewise the inconvenience of emitting an unpleasant smell, pernicious to the animal œconomy. The addition of alkali corrects and prevents this effect.

In the diocese of Lodeve, the young shoots of the Spanish genet are prepared by a very simple process. It is sown on the high grounds, where it is left for three years; at the end of which time the sprigs or young shoots are cut, and formed into bundles, which are sold from twelve to fifteen sous each. The first operation consists in crushing them with a beetle. The following day they are laid in a running stream, with stones upon them, to prevent their being washed away. In the evening they are taken out, and laid in a heap on the banks of the river, upon straw or fern, covering them with the same, and loading the heap with stones: this operation they call *mettre à couvert*. Every evening they throw water on the heap. At the end of eight days they open the mass, and find that the bark is easily separated from the wood. They take the packets, one after the other, and beat and rub them strongly with a flat stone, till the epidermis of the extremities is well cleared off, and the whole stem becomes white. It is then hung to dry; and the bark which was separated from the ligneous substance, is carded and spun, and made into very useful cloth. The peasants are acquainted with no other linen for cloths, sacks, shirts, &c. Every one prepares his own, none being made for sale.

The genet, *genista juncea*, has likewise the advantage of affording a green food to cattle during the winter; at the same time that it supports the earth by its roots, and prevents its being carried down into the valleys. The bark of the mulberry tree may be treated in the same manner. Olive de Serres has described a good process for this purpose.

It is the skeleton formed by the vegetable fibre only, and deprived of all foreign matter, which is used to make cloth; it is the most incorruptible principle of vegetation, and when



this fibre, being converted into cloth, can no longer be used as such, it is subjected to extreme division, to convert it into paper. The operations for this purpose are the following:—The rags are cleaned, and laid in water to rot; after which they are torn by hooked pestles moved by water: the second pestles under which they are made to pass, are not armed with hooks like the first, but merely with round nails: the third are of wood only. By this means the rags are converted into a paste, which is attenuated still more by boiling. This paste is received in wire moulds, dried, and forms blotting paper. Writing paper is dipped in size, and sometimes glazed.

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## CHAPTER VI.

Concerning the Action of Air, of Heat, and of Water upon Vegetables.

WHEN the various juices of vegetables are diffused in water, and the action of this fluid is favoured by the combined action of air and heat, a decomposition of these juices ensues. The oxygenous gas may be considered as the first agent of fermentation: it is afforded either by the atmosphere, or by the water which is decomposed.

It was from an observation of these facts that Becher thought himself authorized to consider fermentation as a kind of combustion:—*Nam combustio, seu calcinatio per sortem ignem, licet putrefactionis species, eidemque analogia sit—fermentatio ergo definitur, quod sit corporis densioris rarefactio, particularumque aërearum interpositio, ex quo concluditur debere in aëre fieri, nec nimium frigido nec nimium calido, ne partes raribiles expellantur, in aperto tamen vase, vel tantum vacuo ut partes rarefieri queant; nam stricta clusura, et vasis impletio, fermentationem totaliter impedit.*—Becher, *Phys. Subst. s. i. 15, v. cap. 11, p. 313.*

The conditions necessary for the establishment of fermentation are—1. The contact of pure air. 2. A certain degree of heat. 3. A quantity of water more or less considerable, which produces a difference in the effects.

The phenomena which essentially accompany fermentation are—1. The production of heat. 2. The absorption of oxygenous gas.



Fermentation may be assisted—1. By increasing the mass of fermentable matter. 2. By using a proper leaven.

—1. By increasing the fermentable mass, the principles on which the air must act are multiplied; consequently the action of this element is facilitated; more heat is therefore produced by the fixation of a greater quantity of air; and consequently the fermentation is promoted by the two causes which most eminently maintain it, heat and air.

2. Two kinds of leaven may be distinguished. 1. Bodies eminently putrescible, the addition of which hastens the fermentation. 2. Those which already abound with oxigene, and which consequently afford a greater quantity of this principle of fermentation. This effect is produced by the inhabitants of the banks of the Rhyn, by throwing fresh meat into the vintage, to hasten the spirituous fermentation (Linné *Amœnit. Acad. Dissert. de Genesi Calculi*): and so likewise the Chinese throw excrements into a kind of beer, made of a decoction of barley and oats. And on this account it is that the acids, the neutral salts, chalk, rancid oils, and the metallic calces, &c. hasten fermentation.

The products of fermentation have caused different species to be distinguished: but this variety of effects depends on the variety of principles in the vegetables. When the saccharine principle predominates, the result of the fermentation is a spirituous liquor; when, on the contrary, the mucilage is most abundant, the product is acid; if the gluten be one of the principles of the vegetable, there will be a production of ammoniac in the fermentation: so that the same fermentable mass may undergo different alterations, which always depend on the nature and respective properties of the constituent principles, the susceptibility of change, &c. Thus a saccharine liquid, after having undergone the spirituous fermentation, may be subjected to the acid fermentation by the decomposition of the mucilage which had resisted the first fermentation: but in all cases the concurrence of air, water, and heat, is necessary to develop fermentation. We shall therefore confine ourselves to the examination of these three agents: 1. On the juices extracted from vegetables, and diffused in water, which constitutes the spirituous and acid fermentations; 2. On the vegetable itself, which will lead us to the formation of vegetable mould, ochres, &c.

## ARTICLE I.

Concerning the Spirituous Fermentation and its Products.

That fermentation is distinguished by the name of Spirituous, which affords ardent spirit, or alcohol, as its product or result.

It may be considered as a fundamental principle, that no substances are capable of this fermentation but saccharine bodies. Pure sugar mixed with water forms taffia, or rum, by fermentation; and we find this principle in the analysis of all the bodies which are susceptible of it.

In order to develop this fermentation, there is required,  
1. The access of air. 2. A degree of heat between ten and fifteen of Reaumur. 3. The division and expression of the juice contained in the fruits, or in the plant. 4. A mass or volume somewhat considerable.

We will make the application of these principles to the fermentation of grapes. When these are ripe, and the saccharine principle is developed, they are then pressed, and the juice which flows out is received in vessels of a proper capacity, in which the fermentation appears, and proceeds in the following manner:—At the end of several days, and frequently after a few hours, according to the heat of the atmosphere, the nature of the grapes, the quantity of the liquid, and the temperature of the place in which the operation is performed, a movement is produced in the liquor, which continually increases; the volume of the fluid increases; it becomes turbid and oily; carbonic acid is disengaged, which fills all the unoccupied part of the vessel, and the temperature rises to the 18th degree. At the end of several days these tumultuous motions subside, the mass falls, the liquor becomes clearer, and is found to be less saccharine, more odorant, and of a red colour, from the reaction of the ardent spirit upon the colouring matter of the pellicle of the grape.\*

The causes of an imperfect fermentation are the following:

1. If the heat be too little, the fermentation languishes, the

\* Richardson, in his Treatise on Brewing, insists much on the difference between the specific gravity of the fluid before and after fermentation, which he considers as proportional to the strength or inebriating quality of the fluid. Fermented liquors have a less specific gravity than they possessed before the fermentation. This circumstance well deserves the attention of the manufacturer. T.

saccharine and oily matters are not sufficiently elaborated, and the wine is unctuous and sweet.

2. If the saccharine body be not sufficiently abundant, as happens in rainy seasons, the wine is weak, and the mucilage which predominates causes it to become sour by its decomposition.

3. If the juice be too watery, concentrated and boiling must is added.

4. If the saccharine principle be not sufficiently abundant, the defect may be remedied by the addition of sugar. Macquer has proved that excellent wine may be made of verjuice and sugar; and Mr. De Bullion has made wine at Bellejames with the verjuice of his vine rows and moist sugar.

There have been many disputes to determine whether grapes should be pressed with the stalks or without. It seems to me that this depends on the nature of the fruit. When they are highly charged with saccharine and mucilaginous matter, the stalk corrects the insipidity of the wine by its bitter principle: but when, on the contrary, the juice is not too sweet, the stalk renders it drier, and very rough.

The wine is usually taken out of the fermenting vessels at the period when all the phenomena of fermentation have subsided. When the mass is settled, the colour of the liquor is well developed, when it has become clear, and its heat has disappeared; it is put into casks, where, by a second insensible fermentation, the wine is clarified, its principles combine more perfectly together, and its taste and smell become more and more developed.

If this fermentation be stopped or suffocated, the gaseous principles are retained, and the wine is brisker, and more of the nature of must. Becher had very proper ideas of the effects of these two fermentations.

*Distinguitur autem inter fermentationem apertam et clausam: in aperta potus fermentatus sanior est, sed debilior; in clausa non ita sanus, sed fortior: causa est quod evaporantia rarefacta corpuscula imprimis magna adhuc silvestrium spirituum copia, de quibus antea egimus, retineatur et in ipsum potum se precipitet, unde valde eum fortem reddit.* Becher, *Phys. Subt. lib. 1, v. V. cap. 11, p. 313.*



It appears, from the interesting experiments of the Marquis de Bullion, that the vinous fermentation does not take place unless tartar be present.

By evaporating the must of grapes, a salt is obtained, which has the appearance of tartar, and forms salt of Seignette with the alkali of soda. A large quantity of sugar is also obtained. For this purpose the tartar is first to be extracted; after which, the must having evaporated to the consistence of a thick syrup, is to be left for six months in a cellar. At the expiration of this time, the sugar is found in a confused state of crystallization; and this being washed with spirit of wine, to carry off the colouring part, becomes very fine and pure.

Wine deprived of its tartar ferments no more, and the fermentation is in proportion to the abundance of the tartar. Cream of tartar produces the same effect.

It appears that these salts act only as leavens, to facilitate the decomposition of the saccharine principle.

The juice of grapes is not the only vegetable fluid susceptible of the spirituous fermentation.

Apples contain a juice which easily ferments, and produces cyder. Wild apples are usually employed for this purpose. These are bruised, and the juice pressed out, which ferments, and exhibits the same phenomena as the juice of grapes.

In order to have cyder fine, it is to be decanted off the lees as soon as the tumultuous fermentation has subsided, and it begins to be clear. Sometimes, in order to render it milder, a certain quantity of the juice of apples recently expressed is added, which produces a second fermentation in the cyder less strong than the first. The cyder which is left to stand on the lees acquires strength by that means. Cyder affords the same products as wine; but the brandy obtained from it has a disagreeable flavour, because the mucilage, which is very abundant in the cyder, is altered by the action of the heat of distillation. But if it be cautiously distilled, it affords excellent brandy, according to the experiments of M. Darcet.

The juice of the harshest kind of pears affords, by fermentation, a kind of cyder called Perry.



Cherries likewise afford a tolerably good wine; and a kind of brandy is obtained from them, which the Germans call *Kirchenschwaffer*.

In Canada the fermentation of the saccharine juice of the maple affords a very good liquor; and the Americans, by fermenting the impure syrups of sugar with two parts of water, form a liquor which affords the spirit called *Taffia*, or *Rum*, by the English.

A drink called *Beer* is likewise prepared with certain grain; such as wheat, oats, and barley; but more especially with the latter. 1. The grain is made to sprout or vegetate, by steeping it in water, and placing it in a heap. By this means the glutinous principle is destroyed. 2. It is torrefied or stoved, to stop the progress of the fermentation, and fit it for the mill. 3. It is sifted, to separate the sprouts or radicles. 4. It is ground into a very coarse flour, named *Malt*. 5. The malt is infused in hot water, in the *mash-tub*. This dissolves the sugar and the mucilage, and is called the *first wort*. It is then drawn off, heated, and again poured on the malt, which forms the *second wort*.\* 6. This infusion, or *wort*, is boiled with a certain quantity of hops, which communicate an extractive resinous principle to it. 7. An acid leaven, or ferment, is added, and it is poured into a cooler, where it undergoes the *spirituous fermentation*. When the fermentation has subsided, it is stirred and put into casks, where it continues to ferment, and throws off a frothy scum by the bung, which becomes sour, and serves as a ferment for future brewings, under the name of *Yeast*.

The product of all the substances is a liquor more or less coloured, capable of affording ardent spirit, by distillation, of an aromatic and resinous smell, a penetrating hot taste, which stimulates the action of the fibres.

Wine is an excellent drink, and is also used as the vehicle of certain medicines. Such are—1. The *emetic wine*, which is prepared by digesting two pounds of good white wine on four ounces of the *crocus metallorum*: 2. *Chalybeated wine*, made by digesting one ounce of steel filings in

\* In our breweries this practice is only used for double ales: and the strengths in other cases are regulated by the number of times the same malt is wetted, and the time of infusion. The third mashing affords small beer. T.

two pounds of white wine: 3. The wines in which plants are infused; such as wormwood, sorrel, and the liquid laudanum of Sydenham, which is made by digesting for several days two ounces of sliced opium, one ounce of saffron, one dram of pounded cinnamon and of cloves, in one pound of Spanish wine.

We shall proceed to examine the constituent principles of these spirituous liquors, by taking that of grapes for an example. The moment the wine is in the cask, a kind of analysis takes place, which is announced by the separation of some of its constituent principles; such as the tartar which is deposited at the sides, and the lees which are precipitated to the bottom: so that there remain only the ardent spirit and the colouring matter diffused in a volume of liquid, which is more or less considerable.

1. The colouring principle is of a resinous nature, and is contained in the pellicle of the grape; and the fluid is not coloured until the wine is formed; for until then there is nothing which can dissolve it: and hence it is that white wine may be made of red grapes, when the juice of the grape is expressed, and the husk thrown away.

If wine be evaporated, the colouring principle remains in the residue, and may be extracted by spirit of wine.

Old wines lose their colour, a pellicle being precipitated, which is either deposited on the sides of the bottles, or falls to the bottom. If wine be exposed to the heat of the sun during the summer, the colouring matter is detached in a pellicle, which falls to the bottom; when the vessel is opened, the discolouring is more speedy, and it is effected in two or three days during the summer. The wine thus deprived of its colour is not perceptibly weakened.

2. Wine is usually decomposed by distillation; and the first product of the operation is known by the name of Brandy.

Brandies have been made since the thirteenth century; and it was in Languedoc where this commerce first originated. Arnould de Villeneuve appears to have been the author of this discovery. The alembics in which wine was distilled consisted for a long time of a kind of boiler, surmounted with a long cylindric neck, very narrow, and terminating in an hollow hemisphere, in which the vapours were condensed.

To this small capital was adapted a narrow tube, to convey the fluid into the serpentine or worm pipe. This distillatory apparatus has been successively improved. The column has been considerably lowered; and the stills generally adopted for the distillation of wines in Languedoc are nearly of the following form. The body of the still is flat at bottom, and the sides rise perpendicularly to the height of twenty-one inches. At this height the sides incline inwards, so as to diminish the opening to twelve inches. This opening ends in a neck of several inches long, which receives the basis of a small covering called the head, which approaches to the figure of an inverted cone. From the angle of the upper base of the capital, there issues a small beak, intended to receive the vapours of brandy, and transmit them into the worm-pipe to which it is adapted. This worm-pipe has five or six turns, and is placed in a tub, which is kept filled with cold water, to condense the vapours.

The body of the still is usually surrounded by the masonry as high as the neck, and the bottom only is exposed to the immediate action of the fire. An ash-hole, which is too small, a fire-place large enough, and a chimney placed opposite the door of the fire-place, constitute the furnaces in which these stills are fixed.

The still is charged with between five and six quintals of wine; the distillation is made in eight or nine hours; and from sixty to seventy-five pounds of pit-coal are consumed in each distillation.

Every judicious person must be aware of the imperfection of this apparatus. Its principal faults are the following :

1. The form of the body is such as to contain a column of wine of considerable height and little breadth, which being acted on by the fire at its base, is burned at that part before the upper part is heated.

2. The contraction of the upper part renders the distillation more difficult and slow. In fact, this inclined part being continually struck by the air, condenses the vapours, which incessantly return into the boiler. It likewise opposes the free passage of the vapours, and forms a kind of eolipile, as Mr. Beaumé has observed; so that the vapours, being compressed at this narrow neck, react on the wine, and oppose its further ascent.



3. The capital is not constructed in a more advantageous manner. The upper part becomes of the same temperature as the vapours, which cannot therefore be condensed, and, by their reaction, either suspend or retard the distillation.

4. In addition to this imperfect form of the apparatus, is joined the most disadvantageous method of administering the fire. The ash-hole is every where much contracted; the fire-place is very large, and the door shuts badly. In consequence of this, a current of air passes between the combustible matter and the bottom of the still, and the flame is driven into the chimney, without being turned to advantage. A violent fire is therefore required to heat the stove only to a moderate degree, in this defective construction.

Several other degrees of perfection have been successively obtained in the manufactories of Mr. Joubert: but I have judged it possible to add still more to what was known, and the following are the principles I set out from.

The whole art of distillation is reduced to the two following principles:—1. The vapours ought to be disengaged, and raised in the most economical manner: 2. And their condensation ought to be as speedy as possible.

To answer the first of these conditions, it is necessary that the boiler should present the largest possible surface to the fire, and that the heat should be every where equally applied.

2. The second condition requires that the ascent of the vapours should not be impeded, and that they should strike against cold bodies, which shall rapidly condense them.

The stills which I have constructed upon these principles are more broad than high; the bottom is concave, in order that the fire may be nearly at an equal distance from all the points of its surface; the sides are elevated perpendicularly in such a manner that the body exhibits the form of a portion of a cylinder; and this body is covered with a vast capital, surrounded by its refrigeratory. This capital has a groove, or channel, projecting two inches at its lower part within: the sides have an inclination of sixty five degrees; because I have ascertained that, at this degree, a drop of brandy will run along without falling again into the still. The beak of the capital is as high and as wide as the capital itself, and insensibly diminishes till it comes to the worm-pipe itself. The refrigeratory accompanies the beak, or neck,



and has a cock at its further end, which suffers the water to run out, while its place is supplied by other cold water, which incessantly flows in from above.

When the water of the refrigeratory begins to be warm, a cock is then opened, that it may escape in proportion as it is more plentifully supplied from above. By this means the water is kept at an equal temperature, and the vapours which strike against the sides of the head are condensed, at the same time that those which rise suffer no obstacle, as they are subjected to no contraction of space. In this construction, the worm-pipe may be almost dispensed with, because the water in the worm-tub does not become perceptibly heated.

These proceedings are very economical and advantageous; for the quality of the brandy is better, and the quantity is larger.

The distillation of the wine is kept up until the product is no longer inflammable. This brandy is put into casks, when it becomes coloured by the extraction of a resinous principle contained in the wood.

The wine of our climates affords one-fifth or one-fourth of brandy, of the proof strength of commerce.

The distillation of brandy by a more moderate heat affords a more volatile fluid, called Spirit of Wine, or Alcohol. To make common spirit of wine, brandy is taken and distilled on a water bath by distillation\*. This spirit of wine may be purified and rectified by subsequent distillations, and taking only the first portions which come over.

Alcohol is a very inflammable and very volatile substance. It appears to be formed by the intimate union of much hydrogen and carbone, according to the analysis of Mr. Lavoisier. This same chemist obtained eighteen ounces of water by burning one pound of alcohol. If well-dephlegmated alcohol be digested upon calcined potash, and afterwards distilled, a very sweet alcohol is obtained, and a saponaceous

\* The ardent spirit sold in London by the name of Spirit of Wine, or Lamp Spirit, is made by the rectifiers of malt and melasses spirit in London, by distillation of the residues of their compounded spirits. It is pretty constantly of the specific gravity of 0,845 at the temperature of 60 Fahrenheit; and may, by very careful rectification, be brought nearly up to 0,820. Dry alkali deprives it of more of its water. On the subject of the strength of spirits, consult Blagden in Phil. Trans. vol. lxxxi. T.

extract, which affords alcohol, ammoniac, and an empyreumatic oil. In this experiment, the formation of volatile alkali appears to arise from the combination of the hydrogen of the alcohol with the nitrogen of the pot-ash.

There are various methods used in the arts to judge of the degree of concentration of spirit of wine. Gunpowder is put into a spoon, and moistened with spirit of wine, which is set on fire: if the powder takes fire, the spirit is considered to be good; but the contrary, if this effect does not take place. But this method is fallacious, because the effect depends on the proportion in which the spirit of wine is used; a small quantity always inflames the powder; and a strong dose never produces this effect, because the water which remains soaks into the powder, and defends it from the combustion.

The areometer of Mr. Baumé is not to be depended on; because, in the use of it, no account is kept of the temperature of the atmosphere, which, by changing the density of the spirit of wine, is productive of a change in the result as given by this instrument. That of Mr. Bories is more accurate, because the thermometer is adapted to it; and is now used in commerce.

Alcohol is the solvent of resins, and of most aromatic substances; and consequently it forms the basis of the art of the varnisher and of the perfumer.

Spirit of wine combined with oxigene forms a liquor nearly insoluble in water, which is called Ether.

Ether has been formed with most of the known acids.

The most ancient of all is the vitriolic or sulphuric ether. To make this, a certain quantity of alcohol is put into a retort, and an equal weight of concentrated sulphuric acid is gradually added. The mixture is shaken and agitated, to prevent the retort from breaking by the partial effect of the heat which arises. The retort is then placed on a heated sand bath, a receiver is adapted, and the mixture is heated to ebullition. Alcohol first passes over; soon after which, streams of fluid appear in the neck of the retort, and within the receiver, which denote the rising of the ether. Its smell is agreeable. Vapours of sulphureous acid succeed the ether; and the receiver must be taken away the moment they appear. If the distillation be continued, sulphureous ether is obtained, and the oil which is called *Ethereal Oil*,

or the sweet oil of wine; and that which remains in the retort is a mixture of undecomposed acid, sulphur and a matter resembling bitumens.

We see that in this operation the sulphuric acid is decomposed; and that the oxigene, by combining with the hydrogen and the carbone of the alcohol, has formed three states, which we also find in the distillation of some bitumens—1. A very volatile oil or ether. 2. Etherial oil. 3. Bitumen.

If the sulphuric acid be digested upon ether, it converts the whole gradually into etherial oil.

When the ether is mixed with sulphureous vapours, it must be rectified by a gentle heat; a few drops of alkali being first poured in, to combine with the acid.

Sulphuric ether may be made very œconomically, by using a leaden still with a head of copper well tinned. In this way I prepare it by the quintal without any difficulty.

Mr. Cadet has proposed to pour on the residue of the retort one third part of good alcohol, and to distil it in the usual way.

Ether is very light, very volatile, and of a pleasant smell. It is so easily evaporated, that if a fine rag be steeped in this liquor, then wrapped round the ball of a thermometer, and the instrument be agitated in the air, the thermometer sinks to the freezing point\*.

Ether easily burns, and exhibits a blue flame. It is very sparingly soluble in water.

Ether is an excellent antispasmodic. It mitigates pains of the colic as if by enchantment, as it does likewise external pains. The celebrated Bucquet had accustomed himself so

\* Mr. Cavallo has described, in the Philosophical Transf. for 1781, a pleasing experiment of freezing water by means of ether. The ether is put into a vial so as not completely to fill it; and in the neck of this vial is fitted, by grinding, a tube whose exterior end is drawn out to a capillary fineness. Whenever the bottle thus stopped is inverted, the ether is urged out of the tube in a fine stream, in consequence of the pressure exerted by the elastic etherial vapour which occupies the superior space of the bottle. This stream is directed on the outside of a small glass tube containing water, which it speedily cools down to the freezing point; at which instant the water becomes suddenly opaque, in consequence of the icy crystallization. If a bended wire be previously immersed in the water, it may afterwards be drawn out, and the ice along with it. T.



much to this drink, that he took two pints per day: a rare example of the power of habit on the constitution.

The mixture of two ounces of spirit of wine, two ounces of ether, and twelve drops of ethereal oil, forms the anodyne liquor of Hoffman.

Messrs. Navier, Woulfe, Laplanche, Bogue, and others, have described various processes for making nitric ether, which are more or less easily imitated. For my part, I take equal parts of alcohol, and nitric acid of commerce, of the strength of between thirty and thirty-five degrees. I put the whole into a tubulated retort, which I fit to a furnace, and adapt two receivers one succeeding the other. The first receiver is immersed in a vessel of water. The second is surrounded by a wet cloth; and a siphon communicates from its tubulure to a vessel of water in which it is plunged. When the heat has penetrated the mixture, much vapours are disengaged, which are condensed in striae, on the internal surfaces of the receivers, whose external surface is kept constantly cold. The ether which I obtain is very pure and very abundant\*.

When the precaution of distilling it properly is attended to, this ether becomes nearly similar to the vitriolic. Messrs. de Laffone and Cornette have observed that it was more sedative.

The distillation of the muriatic acid with alcohol produces only a mixture of these two liquors, which is called the Dulcified Muriatic Acid.

Before the theory of ethers, and the simple process of combining a surplus of oxigene with the muriatic acid, were known, methods were invented to procure the muriatic ether, but substances were always made use of in which the muriatic acid was oxygenated. In this manner it was that the baron

\* The ingenious author has forgotten to caution the inexperienced chemist against the danger of mixing these two liquors. The nitrous acid must be very gradually added to the spirit of wine, by small portions at a time. It is said, and with reason, to be of great importance, that the nitrous acid be added to the spirit, and not the spirit to the acid: for, in this last case, the mixture will, during the greatest part of the time of the operation of combining the fluids, consist of a large portion of acid, with a smaller portion of spirit; whereas, where the contrary method is adopted, the proportion of spirit will always be greater than that of the acid, until the last quantity of acid is added. T.



de Bornes proposed the concentrated muriate of zinc, mixed and distilled with alcohol; and that the marquis de Courtauvau distilled the mixture of a pint of alcohol with two pounds and a half of the fuming muriate of tin.

The theory of the formation of ether has in our time led to simpler processes.

Mr. Pelletier introduces a mixture of eight ounces of manganese, and a pound and a half of the muriate of soda, in a large tubulated retort; twelve ounces of sulphuric acid, and eight ounces of alcohol, are afterwards added. Distillation is then proceeded on; and ten ounces of a very ethereal liquor are obtained, from which four ounces of good ether are afforded by distillation and rectification.

The very concentrated muriatic acid, distilled from manganese in the apparatus of Woulfe, affords more ether. It is even sufficient, for this purpose, to pass the oxygenated muriatic acid through good alcohol, to convert it into ether.

This muriatic ether has the greatest analogy with the sulphuric. It differs from it in two characters only—1. It emits, in burning, a smell as penetrating as that of the sulphuric acid. 2. Its taste is styptic, resembling that of alum.

From these experiments it is evident that ether is merely a combination of alcohol with the oxygen of the acids made use of. I have even obtained an ethereal liquor by repeated distillations of good alcohol from the red oxide of mercury.

The idea of Macquer, who considered ether as spirit of wine dephlegmated, or deprived of water, had little foundation; for the distillation of the spirit of wine from the most concentrated or driest alkali; never affords any thing but spirit of wine more or less dephlegmated.

#### Concerning Tartar.

Tartar is deposited on the sides of casks during fermentation: it forms a lining more or less thick, which is scraped off. This is called crude tartar, and is sold in Languedoc from ten to fifteen livres the quintal.

All wines do not afford the same quantity of tartar. Newmann remarked that the Hungarian wines left only a thin stratum; that the wines of France afforded more; and that the Rhenish wines afforded the purest and the greatest quantity.

Tartar is distinguished, from its colour, into red or white: the first is afforded by red wine.

The purest tartar exhibits an imperfectly crystallized appearance: the form is the same as we have assigned to the acidulous tartrate of potash; and it is this quality which is called grained tartar (*tartre grenu*) in our refineries at Montpellier.

The taste of tartar is acid and vinous. One ounce of water, at the temperature of ten degrees above 0 of Reaumur, dissolves no more than ten grains: boiling water dissolves more, but it falls down in crystals by cooling.

Tartar is purified from an abundant extractive principle by processes which are executed at Montpellier and at Venice.

The following is the process used at Montpellier:—The tartar is dissolved in water, and suffered to crystallize by cooling. The crystals are then boiled in another vessel, with the addition of five or six pounds of the white argillaceous earth of Murviel to each quintal of the salt. After this boiling with the earth, a very white salt is obtained by evaporation, which is known by the name of Cream of Tartar, or acidulous tartrate of potash.

M. Desmaretz has informed us (*Journal de Phys.* 1771) that the process used at Venice consists—1. In drying the tartar in iron boilers. 2. Pounding it, and dissolving it in hot water, which by cooling affords purer crystals. 3. Redissolving these crystals in water, and clarifying the solution by whites of eggs and ashes.

The process of Montpellier is preferable to that of Venice. The addition of the ashes introduces a foreign salt, which alters the purity of the product.

The acidulous tartrate of potash crystallizes in tetrahedral prisms cut off slantwise.

This salt is used by the dyers as a mordant: but its greatest consumption is in the north, where it is used at table as a seasoner.

Tartar appears to exist in the must, and consequently in the grape itself. This has been ascertained by the experiments of De Rouelle and the marquis de Bullion.

This salt exists in many other vegetables. It is sufficiently proved that tamarisc and sumach contain it; and the same is

true of the barberry, of balm, carduus benedictus, restharrow, water-germander, and sage.

The acidulous tartrate of potash may be decomposed by means of fire, in the way of distillation; in which case the acid and the alkali are obtained separately. This decomposition may also be effected by the sulphuric acid.

The celebrated Scheele has described a process of greater accuracy for obtaining the acid of cream of tartar.

Two pounds of the crystals are dissolved in water, into which chalk is thrown by degrees, till the liquid is saturated. A precipitate is formed, which is a true tartrate of lime, is tasteless, and cracks between the teeth. This tartrate is put into a cucurbit; and nine ounces of sulphuric acid, with five ounces of water, are poured on it. After twelve hours digestion, with occasional stirring, the tartareous acid is set at liberty in the solution, and may be cleared of the sulphate of lime by means of cold water.

This tartareous acid affords crystals by evaporation; which, when exposed to the fire, become black, and leave a spongy coal behind.

Treated in a retort, they afford an acid phlegm, and some oil.

The taste of this acid is very sharp.

It combines with alkalis, with lime, with barytes, alumine, magnesia, &c.

The combination of potash with this acid forms cream of tartar, when the acid is in excess; which is capable of entering into combinations, and forming triple salts. Such is the salt of Seignette, or tartrate of soda, which crystallizes in tetrahedral rhomboidal prisms.

The acidulous tartrate of potash is very sparingly soluble in water. Boiling water dissolves only one twenty-eighth part. The addition of borax has been proposed to facilitate the solution; as likewise sugar, which is less efficacious than borax, but makes a very agreeable and purgative lemonade with this salt.

## ARTICLE II.

### Concerning the Acid Fermentation.

The mucilaginous principle is more especially the substance on which the acid fermentation depends; and when

it has been destroyed, in old and generous wines, they are no longer capable of alteration, without the addition of a gummy matter, as I find from my own experiments. It is not true, therefore, to say that all substances which have passed through the vinous fermentation, are capable of passing to the state of vinegar; since this change depends on the mucilage, which may not in all cases be present.

There are, therefore, three causes necessary to produce the acid fermentation in spirituous liquors.

1. The existence of mucilaginous matter, or mucilage.
2. A degree of heat between eighteen and twenty-five degrees of Reaumur.
3. The presence of oxygenous gas.

The process indicated by Boerhaave for making vinegar, is still the most frequently used. It consists in fixing two casks in a warm room or place. Two false bottoms of basket-work are fixed at a certain distance from the bottom, upon which the refuse of grapes and vine twigs are placed. One of these tuns is filled with wine, and the other only half filled. The fermentation begins in this last; and, when it is in full action, it is checked by filling the cask up with wine out of the other. The fermentation then takes place in the last-mentioned cask, that remained half filled; and this is checked in the same manner by pouring back the same quantity of liquid out of the other: and in this way the process is continued till the vinegar is made, which is usually in about fifteen days.

When the fermentation develops itself, the liquid becomes heated and turbid; a great number of filaments are seen in it; it emits a lively smell; and much air is absorbed, according to the observation of the abbé Rozier.

A large quantity of lees is formed, which subsides when the vinegar becomes clear. This lees is very analogous to the fibrous matter.

Vinegar is purified by distillation. The first portions which pass over are weak; but soon afterwards the acetous acid rises, and is stronger the later it comes over in the distillation. This fluid is called Distilled Vinegar; and is thus cleared of its colouring principle, and the lees, which is always more or less abundant.

Vinegar may likewise be concentrated by exposing it to the frost. The superabundant water freezes, and leaves the acid more condensed.



The presence of spirit of wine, mucilage, and air, are necessary to form vinegar. Scheele has made it by decomposing the nitric acid upon sugar and mucilage. I communicated to the Academy at Paris (vol. 1786) an observation of some curiosity respecting the formation of vinegar. Distilled water, impregnated with vinous gas, affords vinegar: at the end of some months, a deposition is made of a substance in flocks, which is analogous to the fibrous matter of vegetables. When the water contains sulphate of lime, an execrable hepatic odor is developed, a deposition of sulphur is afforded, and all this is owing only to the decomposition of this sulphuric acid.

As in the above experiments I had placed the water above the vinous fluid in fermentation, to impregnate it with the carbonic acid, the alcohol which evaporates with the acid carried the mucilage with it; and the effects, I observed, are referable to this substance.

The acetous acid is capable of combining with a stronger dose of oxigene; and then forms radical vinegar, or the acetic acid.

To form the acetic acid, the metallic oxides are dissolved in the acetous acid; the salt which is obtained being then exposed to distillation, affords the oxygenated acid. It has a very lively smell, is caustic, and its action upon bodies is very different from that of the acetous acid.

This acetic acid has the advantage of forming ether with alcohol. For this purpose, equal parts of the acid and alcohol are to be distilled together. The product of the distillation is to be again added to the residue in the retort; and a small quantity of the water of Babel is likewise to be added. The whole becomes converted into ether.

The combination of the acetous acid with potash forms the acetite of potash.

To make this salt, pure potash is saturated with distilled vinegar, the liquor filtered, and evaporated to dryness in a glass vessel over a very gentle fire. The acetite of potash has a penetrating acid taste; is decomposed by distillation; and affords an acid phlegm, an empyreumatic oil, ammoniac, and a large quantity of very odorant gas, formed of carbonic acid and hydrogen. The coal contains much fixed alkali in a disengaged state. This salt is very soluble in water, and deliquesces in the air.

The sulphuric acid poured upon it, decomposes it; and the products which come over are sulphuric acid and acetic acid.

The acetous acid likewise combines with soda; and this combination is improperly called Crystallizable Terra Foliata. The acetite of soda crystallizes in striated prisms, and does not attract the humidity of the air. When these salts are distilled, they leave a residue, which forms an excellent and very active pyrophorus.

The acetous acid likewise combines with ammoniac. The acetite which is produced is called the spirit of Mindererus. This salt cannot be evaporated without the loss of a considerable part, on account of its volatility: but, by a long evaporation, it affords needle-formed crystals, of a hot and penetrating taste, and attracting moisture from the air. Lime, fixed alkalis, mere heat or fire, and the acids, decompose this salt.

The sulphate of potash, sprinkled with the acetic acid, forms the salt of vinegar.

### ARTICLE III.

#### Concerning the Putrid Fermentation.

In order that vegetables may undergo the two fermentations we have treated of, it is necessary that the juices should be extracted, and presented in a considerable volume. A due degree of heat, together with other circumstances artificially brought together, are likewise necessary; for a grape, left on the stalk, produces neither ardent spirit nor vinegar, but rots. It is this new kind of alteration we shall at present proceed to treat of.

This fermentation is the most natural termination of the vegetable. It is indeed the only end to which the natural course of things is directed; since it is by this means that the exhausted surface of the globe is repaired. The two other fermentations are the mere effects of art, and form no part of the great plan of nature.

The life of the greatest part of vegetables lasts but a few months; but the seeds they deposit assure their re-production. There are other more robust vegetables which support the cold of winter, and only cast their leaves at that period. The annual vegetables, and vivacious plants, are altered by the combined action of the causes we have mentioned; and

the result, according to the degree of decomposition, is either manure, vegetable earth, or ochre.

The conditions of the vegetable fermentation are the following:

1. It is necessary that the organization be impregnated with water. Dried vegetables are preserved without putrefying; and, if they be moistened, their subsequent alteration is prodigiously accelerated. In this manner it is that plants heaped together become heated, blacken, and take fire, if not sufficiently dried. Fires of this kind are not rare, and the theory is not difficult to be explained. Wetted ropes, moist hay heaped together, and in a word every vegetable substance, putrefies or rots with greater facility, the more perfectly its texture is impregnated with water.

2. The contact of air is the second necessary cause in the putrefaction of vegetables. It is reported, in the *Ephemerides of the Curious in Natural Phenomena*, for 1787, that ripe cherries were preserved for forty years, by inclosing them in a vessel well luted, and placed at the bottom of a well.

3. A certain degree of heat is likewise necessary. The heat between five and ten degrees is sufficient to cause decomposition. A greater heat dissipates the humidity, dries the vegetable, and preserves it from putrefaction. Too little heat retards or suspends it.

4. It is likewise necessary, for the due effect of this decomposition, that the vegetables should be heaped together, and their juices abundant. A greater quantity of air is then combined with the vegetable; because the juices and the surfaces are then more considerable; and consequently a greater degree of heat is produced, which accelerates the decomposition.

When vegetables are heaped together, and their texture is softened by the humidity with which they are impregnated, together with their own juices, the phenomena of decomposition are the following; the colour of the vegetable is changed; the green leaves become yellow, the texture becomes lax, and the parts less coherent; the colour of the vegetable itself changes to black or brown; the mass rises, and perceptibly swells up; the heat becomes more intense, and is perceived on approaching the heap; and the



fumes which arise have already a smell, which sometimes is not disagreeable; at the same time bubbles arise, and break at the surface of the liquid, when the vegetables are reduced to a magma. This gas is a mixture of nitrogene, hydrogené, and carbonic acid. At this epocha, likewise, an ammoniacal gas is emitted, which is formed in these circumstances: and, in proportion as these appearances diminish, the strong and offensive odour is succeeded by another which is fainter and milder, and the mass becomes dry. The internal part still exhibits the vegetable structure, when the stem is solid, and the fibrous matter has been the predominating principle; and it then constitutes manure or soil. Hence it arises that the herbaceous plants of a loose texture, and abounding in juices, are not capable of forming manure by their decomposition, but are reduced into a brown mass of little consistence, in which neither fibre nor texture are observed; and this is what, for the most part, forms vegetable mould.

Vegetable mould usually constitutes the first covering or stratum of our globe; and in such cases wherein it is discovered at a depth in the earth, there is no doubt but it has been buried by some revolution.

When a vegetable is converted into earth by this tumultuous fermentation, it still retains the remains of the vegetable, mixed and confounded with the other solid earths and metallic products; and by distillation it affords oil, nitrogene gas, and often hydrogené. It may therefore be considered as an intermediate substance between crude and organic bodies, which participates of the inertia of the one, and the activity of the other; and which in this state is still subject to an insensible fermentation, that changes its nature still more, and deprives it of all its organic contents. These remains of vegetables still contained in vegetable earth, serve as food for other plants that may grow in it. The insensible progress of fermentation, and the suction of vegetables, impoverish the vegetable earth, deprive it of all its organic matter, and there remain only the earths and metallic residue which form the stiff poor soils, and ochres when the ferruginous principle is very abundant.

As this muddy earth is a mixture of all the primitive earths, and some of the metals which are the product of vegetation, as well as the oils, the salts, and other products we



meet with in it; we may consider it as the residue of vegetable decomposition, as the great agent and means by which nature repairs the continual losses the mineral kingdom undergoes. In this mixture of all the principles the materials of all compounds exist; and these materials are so much the more disposed to enter into combinations, as they are in a more divided and disengaged state. It is in these earths that we find diamonds, quartz-crystals, spars, gypsum, &c. It is in this matrix that the bog ores, or ochreous ores of iron, are formed; and it appears that nature has reserved the impoverished residue of vegetables for the reproduction or reparation of the earthy and metallic substances of the globe, while the organic remains are made to serve as nourishment for the growth of other succeeding vegetables.

## PART THE SIXTH.

### CONCERNING ANIMAL SUBSTANCE.

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#### INTRODUCTION.

THE abuse which, at the commencement of this century, was made of the application of chemistry to medicine, occasioned, a short time afterwards, that all the relations between this science and the art of healing were mistaken and rejected. It would no doubt have been more prudent, as well as more useful, to have connected these mistaken applications: but chemistry was not perhaps at that time in a sufficiently advanced state, to be advantageously applied to the phenomena of living bodies; and, even at this day, we see that, though the physiology of the human body is enriched with various interesting facts, there is still much to be done before they will be sufficiently numerous to exhibit a satisfactory mass of doctrine.

The imperfect success of chemistry in that branch of the science which has the study of man for its object, arises from the very nature of the subject itself. Some chemists, by considering the human body as a lifeless and passive substance, have supposed the humours to undergo the same changes as they would have been subject to out of the body; others, from a very superficial knowledge of the constitution of these humours, have pretended to explain all the phenomena of the animal œconomy. All have mistaken or overlooked that principle of life, which incessantly acts upon the solids and fluids; modifies, without ceasing, the impression of external objects; impedes the degenerations which depend on the constitution itself; and presents to us phenomena which chemistry never could have known or predicted by attending to the invariable laws observed in inanimate bodies.

None of the bodies of the mineral kingdom are governed by an internal force. They are all subjected to the direct action of foreign substances, without any modification from any vital principle; and the air, water and fire, produce in them the effects which are necessary, constant, and subject to calculation; whence it happens that we are able to determine, modify, and vary the action of these various agents at pleasure. It is not the same with living bodies: they are all indeed subject to the influence of external bodies; but the effect of these is modified by the reaction of the vital principle, and is varied according to the disposition of that principle. The chemist cannot therefore determine the effects *à priori*, and in a general way. He must search for his results rather in the living body itself than in the operations of his laboratory; and can have no assistance from his analysis but in ascertaining the nature of their component parts. But their action, effects, or transpositions, can only be known by a serious study of the functions of the living body. Chemistry can perform every thing in the mineral kingdom, because every thing depends on the laws of the affinities. But, in the kingdoms of organized beings, this science is subordinate to the laws of the œconomy of living bodies; and its results can only be affirmed to be true, when they are confirmed by observation.

The more the functions of the individual are independent of organization, the less is the empire of chemistry over them, because the effects are modified in a thousand ways; and it is this which renders the application of chemical principles to the phenomena of the human body so very difficult; for the organization is not only very complicated, but the effects are continually varied by the powerful influence of the mind.

There is not however any function in the animal œconomy, upon which the science of chemistry cannot throw some light. If we consider them in the healthy state, we shall perceive that every organ produces some change in the humours it receives; and though the chemist may indeed be ignorant of the manner in which such changes are produced, it is by his art alone that the difference between the original fluid, and that which has been elaborated, can be ascertained. Besides which, the functions of the various organs are exercised upon external objects, and these objects,



come under the consideration of chemistry. We are at present, for example, acquainted with the nature of the air which serves for respiration, its effects on the lungs, and its influence on the animal œconomy. We are even now able to determine whether any air be good or bad, and know how to correct that which is vitiated, &c. We likewise possess some accurate ideas of the nutritive principle of certain substances; and chemistry teaches us how to dispose of the respective aliments, and adapt them to the various circumstances. The analysis of waters is sufficiently perfect to admit of our distinguishing the properties of that fluid relative to health, and to select the best for our own use: so that, while the principle of life presides over and governs all the internal operations of the human body by a mechanism which is very imperfectly known to us, we see nevertheless that all the functions receive an impression more or less direct from external objects; that all the materials used for the support of the machine are supplied from without; that the principle of life which collects and disposes of these materials, after laws unknown to us, is capable neither of choosing nor rejecting them; and that the functions would be very speedily altered, if chemistry, founded on observation, were not careful to remove the noxious, and select such bodies as are of advantage to the system. Chemistry therefore can do nothing in the arrangement of the materials, but possesses unlimited power in their selection and preparation.

When the organization is deranged, this defect of order can arise only from external or internal causes. In the first case, the analysis of the air, the water, and the food, will afford accurate notions sufficient to re-establish the functions. In the second, the chemical examination of the humours may afford information sufficient to direct the physician in pointing out the most suitable remedy. Sometimes the humours are decomposed in the body, as *in vitro*. We observe all the phenomena of a degeneration and complete disunion of the principles which compose the blood, in the scurvy, cachexy, malignant fevers, &c. It seems as if, in such cases, the vital principle abandoned the government, and left the solids and fluids to the destructive action of external agents; in consequence of which they become decomposed in the same manner as they usually do when separated from the body.



When the principle of animality is once extinguished, the same causes which maintained the functions, and whose effects were modified by that principle of life, now act with their whole energy on the body, and decompose it. Chemistry has discovered methods of extracting from these dead bodies a variety of substances of use in the arts and in pharmacy.

Chemistry is therefore applicable to the animal œconomy in the state of health and in the state of sickness.

The chemical art has marked the limits between vegetable and animal substances. These last afford ammoniac by putrefaction, while the fermentation of the former develops ardent spirit. The latter leave a coal which burns easily; while the former become converted into a coal almost incombustible. Animal matters contain much nitrogene, which may be disengaged by means of nitric acid. The interesting Memoirs of Mess. Berthollet and De Fourcroy on animal substances, may be consulted to great advantage.

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## CHAPTER I.

### Concerning Digestion.

THAT humour which is known by the name of the Gastric Juice, is separated by glands placed between the membranes which line the stomach; and from these it is emitted into the stomach itself.

In order to obtain the gastric juice in a state of purity, the animals intended to furnish it are kept fasting for two days, after which the stomach is extracted. In this manner Spallanzani obtained thirty-seven ounces of this juice out of the two first stomachs of a sheep. The same naturalist caused animals to swallow thin tubes of metal, pierced with several holes, into which he had put small sponges, very clean and dry. He caused crows to swallow eight at a time, which were vomited up at the end of three hours and a half. The juice which he obtained was yellow, transparent, salt, bitter, and leaving very little sediment, when the bird was fasting. The gastric juice may likewise be procured by the vomiting which is excited by irritation during fasting. M. Scopoli has observed that the most fluid part only is thrown up by

irritation; and that the thicker part does not quit the stomach but by the assistance of an emetic. M. Goffe, who had long accustomed himself to swallow the air, which answered the purpose of an emetic with him, has availed himself of this habit to make some experiments with the gastric juice. He suspends his respiration, receives air into his mouth, and pushes it towards the pharynx with his tongue. This air, rarefied in his stomach, produces a convulsive motion, which clears it of its contents. Spallanzani has observed that eagles spontaneously emit a considerable quantity of gastric juice, when fasting in the morning.

We are indebted to Reaumur and the abbè Spallanzani for very interesting experiments respecting the virtue and effects of the gastric juice in digestion. They caused animals to swallow tubes of metal, perforated in various places, and filled with aliments, to examine their effects. The philosopher of Pavia used purses of thread, and bags of linen and of woollen. He himself swallowed small purses filled with flesh boiled or raw, with bread masticated, and also in its original state, &c. and likewise small cylinders of wood, five lines in length and three in diameter, pierced with holes, and covered with cloth.

M. Goffe, availing himself of the facility with which he was able to vomit by means of the air, has taken all kinds of food, and examined the changes they had undergone, by returning them after intervals more or less remote from the time of deglutition.

From these various experiments it follows—1. That the gastric juice reduces the aliments into an uniform magma, even out of the body, and *in vitro*; and that it acts in the same manner on the stomach after death: which proves that its effect is chemical, and almost independent of vitality. 2. That the gastric juice effects the solution of the aliments included in tubes of metal, and consequently defended from any trituration. 3. That though there is no trituration in membranous stomachs, this action powerfully assists the effect of the digestive juices in animals whose stomach is muscular, such as ducks, geese, pigeons, &c. Some of these animals bred up with sufficient care that they might not swallow stones, have nevertheless broken spheres and tubes of metal, blunted lancets, and rounded pieces of glass, which were

introduced into their stomachs. M. Spallanzani has ascertained that flesh included in spheres sufficiently strong to resist the muscular action, was completely digested. 4. That the gastric juice acts by its solvent power, and not as a ferment; because the ordinary and natural digestion is attended with no disengagement of air, nor inflation, nor heat, nor in a word with any of the phenomena of fermentation.

M. Scopoli observes very well that nothing positive or certain can be asserted respecting the nature of the gastric juice. It is sometimes acid and sometimes insipid. M. Brugnatelli has found in the gastric juice of carnivorous birds, and some others, a disengaged acid, a resin, and an animal substance, united with a small quantity of common salt. The gastric juice of ruminating animals contains ammoniac, an extractive animal substance and common salt. In our time the phosphoric salts have been found disengaged in the gastric juice.

It appears, from the observations of Messrs. Spallanzani and Goffe, that the nature of the gastric juice varies according to that of the aliments. This juice is constantly acid when the diet is vegetable. The abbé Spallanzani affirms, contrary to Messrs. Brugnatelli and Carminati, that birds of prey have never afforded him an acid juice; and he affirms the same of serpents, frogs, fishes, &c.

In order to shew clearly that there is a great difference between the gastric juices of various animals, it is sufficient to observe that the gastric juice of the kite, the falcon, &c. does not dissolve bread, though it digests flesh meat; and that the gastric juice of the turkey, the duck, &c. has no action upon flesh, but converts the hardest grain into a pulp.

Messrs. Jurine, Toggia, and Carminati, have made the most successful applications of the gastric juice in the treatment of wounds.

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## CHAPTER II.

### Concerning Milk.

OF all the animal humours, milk is beyond contradiction the least animalized. It appears to partake of the nature of chyle; it preserves the qualities and character of



the aliments; and for this reason we are induced to place it at the head of the humours of animal bodies.

Milk is separated in organs called breasts or udders; and though the class of animals with breasts exhibits the greatest analogy in the internal construction of these organs, yet the milk varies in the several species. In the human species it is more saccharine; in the cow, milder or softer: the milk of the goat, and of the ass, are slightly astringent; and it is for this reason that they are ordered to be taken in disorders which have weakened and exhausted the human frame\*.

Milk is the first food of young animals. Their weak and feeble stomachs are incapable of digesting and assimilating aliments afforded by the earth; and nature has accordingly provided them a food more animalized, and consequently more analogous to their structure, until their increased strength permits them to use a coarser food.

Hunter has observed that all the animals which disgorge to feed their young, have glands in the stomach, which are formed during the incubation, and afterwards gradually obliterated.

Milk is in general of an opaque white colour, and saccharine taste.

By attending to the various alterations it undergoes when left to itself, or when decomposed by chemical agents, we may arrive at a perfect knowledge of its nature.

Milk exposed to the air is decomposed in a longer or shorter time, according to the degree of heat of the atmosphere. But if the temperature of the atmosphere be hot, and the milk in large quantity, it may pass to the spirituous

\* It seems most probable that the pre-eminence still given to the milk of the ass, arises from no better reason than the loud and sonorous voice of the animal, which, by a kind of reasoning very common among the ancient physicians, has led to a conclusion that the milk of such a creature must be good for the lungs. The root satyrion, the milk of the goat, and many other substances, formerly stood high in medical estimation, for reasons equally obvious and equally superficial. It must not however be denied but that, when the possessor of an exhausted constitution becomes so far obedient to advice as regularly to take asses milk, and attend to other circumstances of regimen, he may find himself benefited; and the asses milk, merely as milk, substituted instead of some less friendly beverage or food, may be entitled to a share in the general effect. T.



fermentation. Marco Polo, the Venetian, who wrote in the thirteenth century, affirms that the Tartars drink mares milk, so well prepared that it might be taken for white wine. Claude Strahlenberg reports that the Tartars extract a vinous spirit from milk, which they call Arki (*Description de l'Empire de Russie*). John George Gmelin, in his *Voyage to Siberia*, affirms that the milk is suffered to become sour, and is afterwards distilled.

M. Nicolas Oseretzkowsky, of St. Petersburg, has proved—1. That milk deprived of its cream cannot produce ardent spirit, either with a ferment or without. 2. That milk agitated in a close vessel affords ardent spirit. 3. That fermented milk loses its spirituous principle by heat, and passes to the state of vinegar.—*Journal de Phys.* 1779.

Milk becomes sour in the summer, and in three or four days the acid has acquired its strength. If the whey be then filtered, and evaporated to half, cheese is deposited. If it be again filtered, and a small quantity of the tartareous acid be added, a quantity of small crystals of tartar are seen to be formed in the course of an hour afterwards, which according to Scheele can (not) arise only from the small quantity of muriate potash (in milk, but from an essential salt\*) which milk always contain.

To separate the various principles contained in sour whey, the following process may be used, which was pointed out by the celebrated Scheele.

Evaporate the sour milk to one eighth. All the acid separates, and remains on the filtre. Pour lime water on the residue; an earth is precipitated, and the lime combines with the acid. The lime may be displaced by the oxalic acid, which forms with it an insoluble oxalite, which falls down, and the acid of milk remains disengaged. The fluid is then to be evaporated to the consistence of honey, and upon this very pure alcohol is to be poured. The sugar of milk, and all the other principles, are insoluble, except the acid. The mass being then filtered, the acid of milk may be separated from its solvent by distillation. This is the acid known by the name of Lactic Acid. It possesses the following characters.

\* The words in the parentheses are added, to render the text conformable to Scheele's Essay. T.

1. When saturated with potash, it affords a deliquescent salt, soluble in alcohol.

2. With soda, a salt not crystallizable, and soluble in alcohol.

3. With ammoniac, a deliquescent salt, which suffers most of its alkali to escape before the heat has destroyed the acid.

4. Barytes, lime, and alumine, form with it salts which are deliquescent.

5. Magnesia affords small crystals, which are resolved into a liquor.

6. Bismuth, cobalt, antimony, tin, mercury, silver, and gold, are not attacked by it either hot or cold.

7. It dissolves iron and zinc, and produces hydrogenous gas. The solution of iron is brown, and does not afford crystals: that of zinc crystallizes.

8. With copper it assumes a blue colour, which changes to green, and afterwards to an obscure brown, without crystallizing.

9. When kept in digestion upon lead for several days, it dissolves it. The solution does not afford crystals. A light sediment of a white colour is formed, which Scheele considers as a sulphate of lead.

Whey not four contains a saline substance, known by the name of Sugar of Milk. Messrs. Valgamoze and Lichtenstein have described the process used to obtain this saline substance. The milk is deprived of its cream in the usual manner, and of its curd by rennet. It is then concentrated by evaporation till it has acquired the consistence of honey, after which it is put into moulds, and dried in the sun. This is called Sugar of Milk in Cakes (*sucre de lait en tablettes*). These cakes are dissolved in water, clarified with white of egg, evaporated to the consistence of syrup, and set to crystallize in a cool place. It affords white crystals in rhomboidal parallelepipeds.

Sugar of milk has a slightly saccharine taste, insipid, and as it were earthy. It is soluble in three or four pints\* of hot water. Mr. Rouelle obtained from twenty-four to thirty grains of ashes from one pound of this salt burned. Three-fourths consisted of muriate of potash, and the rest was carbonate of potash.

\* By an oversight for *parts*. T.

Sugar of milk exhibits the same appearances as sugar, either by distillation, or on the fire. This salt\*, treated with the nitric acid, afforded me three gros of oxalic acid in the month of July, 1787 (*Memoir présenté à la Société Royale des Sciences de Montpellier*). Scheele observed the same fact nearly at the same time. I obtained it in beautiful crystals; Scheele, in the form of a white powder†.

If six spoonfuls of good alcohol be mixed with three pints of milk, and the mixture be exposed to heat in close vessels, with the attention to give, from time to time, a slight vent to the gas of the fermentation; the milk is found, in the course of a month, to be changed into good acetous acid, according to Scheele.

If a bottle be filled with fresh milk, and inverted beneath the surface of milk in an open vessel, and this be subjected to a degree of heat a little exceeding that of summer, at the end of twenty-four hours the milk is found to be coagulated; the gas which is developed displaces the milk: a proof

\* The quantity of salt used is not put down. Scheele obtained five drachms of acid of sugar in long crystals, by distilling nitrous acid from twelve ounces of sugar of milk and seven drachms and a half of the peculiar acid of sugar of milk in a white powder. The memoir of Scheele is dated 1780. T.

† I do not see by what oversight it is that our ingenious author seems to confuse the two salts together, which are afforded by treating the sugar of milk with nitrous acid. One, as observed in the preceding note, is the oxalic or saccharine acid, and the other the acid of sugar of milk. The properties of this last (Scheele's Essays, London, 1786) are the following:

1. It is combustible like oil in a red-hot crucible, without leaving any mark of ashes behind.
2. Sixty parts of boiling water, or eighty of cold water, are required to dissolve it.
3. Its taste is sourish, it reddens tincture of litmus, and effervesces with chalk.
4. By destructive distillation it melts, grows black, froths very much; a brown salt, smelling like a mixture of flowers of benzoin and acid of amber, sublimes; a brown liquid, without any appearance of oil, comes over into the receiver, and is found to contain some of the same kind of salt as was sublimed. The sublimed salt is acid, easily soluble in ardent spirit, but more difficultly in water, and burns in the fire with a flame.
5. With all the soluble earths it forms salts insoluble in water.
6. With vegetable alkali it forms a perfectly neutral crystallizable salt, soluble in eight times its weight of boiling water, and separable for the most part by cooling.
7. With mineral alkali it forms a salt which requires only five parts of boiling water for its solution.
8. With volatile alkali it forms a salt which, after being gently dried, has a sourish taste.
9. It does not perceptibly act on the metals; but forms, with their calces, salts of very difficult solubility, which therefore fall down. T.

according to Scheele, that the vinous fermentation has taken place.

To decompose milk, and separate its various constituent parts, rennet, or the milk turned sour in the stomach of calves, is commonly made use of. For this purpose the milk is warmed, and twelve or fifteen grains of rennet is added to each pint. Gallium, the flowers of thistle or artichokes, and the internal membrane of the stomach of birds dried, and reduced to powder, &c. are among the substances which may be used to turn milk. The whey obtained in this manner is turbid; but may be clarified by boiling it with white of egg, and subsequent filtration.

On the mountain of Larzac I have seen the dairy woman plunge her arms up to the elbows in the milk, and change their place from time to time. This was done with a view to hasten the separation of the principles; and it is probable that the heat, and perhaps certain emanations from the arm itself, might favour that effect.

The solid mass which separates from whey, contains two other substances very interesting to be known; namely, cheese and butter.

If any vegetable or mineral acid be put into milk, a coagulation follows, as is well known. The only difference is, that the mineral acid affords less cheese or curd than the vegetable; and the various substances used to coagulate milk, may perhaps act merely by virtue of the acid they contain. Olaus Borrichius obtained no acid from curdled milk at a degree of heat incapable of decomposing it. The coagulum which is afforded in all these cases, contains a substance of the nature of gluten, which forms the cheese; and another substance of the nature of oils, which forms the butter. When cheese is prepared for the table, the butter is not separated, because it renders it milder and more agreeable.

The caustic alkalis dissolve cheese by the assistance of heat. But it is not held in solution by an alkali in milk.

If one part of cheese newly separated, and not dried, be mixed with eight parts of water slightly acidulated by a mineral acid, and the mixture be boiled, the cheese will be dissolved, though it would not have been sensibly acted on by a vegetable acid. This is the cause why the vegetable acids separate a much greater quantity of curd from the same quantity of milk than the mineral acids do.



The cause why salts, gums, sugar, &c. coagulate milk, may be deduced from the greater affinity of the water with these bodies than with the cheese.

The earth of cheese is a phosphate of lime, according to Scheele.

No substance has a stronger resemblance to cheese than the white of egg boiled. White of egg is dissolved in diluted acid, and also in caustic alkali, and in lime-water, and is precipitated from them by acids.

Scheele thinks that the coagulation of white of egg, lymph, and cheese, is owing to the combination of caloric; and he proves his opinion as follows:—Mix one part of white of egg with four parts of water; pour in a small quantity of pure alkali; add as much muriatic acid as is necessary to saturate it, and the white of egg will coagulate. In this experiment there is a change of principles. The heat of the alkali combines with the white of egg, and the alkali with the muriatic acid\*.

Ammoniac dissolves cheese more effectually than fixed alkalis. If a few drops be poured into coagulated milk, it quickly causes the coagulum to disappear.

Concentrated acids likewise dissolve it. Nitric acid disengages nitrogen.

The curd dried, and placed in a proper situation to undergo a commencement of the putrid fermentation, acquires consistence, taste, and colour. In this state it is used at table by the name of Cheese.

At Roquefort, where I have attended the manipulations of the excellent cheese which is made there, care is taken to press the curd well, in order to expel the whey, and to dry it as accurately as possible. After this it is taken into caves, where the temperature is two or three degrees above 0. The fermentation is developed by a small quantity of salt. The

\* The reasoning of Scheele is more fully this:—Heat coagulates white of egg, without diminishing its weight: whence he concludes coagulated white of egg to be a combination of heat with white of egg. Acids expel heat from caustic alkalis when they combine with them, but not from mild alkalis. A very dilute alkali is used in this experiment, that the temperature may not be raised, and nevertheless the effect takes place; but it does not when a mild alkali is used. Whence he concludes that the heat of the caustic alkali, instead of being employed to raise the temperature, has entered into combination with the white of egg, and coagulated it. T.

putrefaction is suspended by scraping the surface from time to time; and the fermentation thus governed by art, and kept under by the coolness of the caves, produces a slow effect upon all the cheese, and successively develops the red and blue colours, of which I have given the etiology in a Memoir on the Fabrication of Cheese at Roquefort, presented to the Royal Society of Agriculture, and printed in the fourth volume of the *Annales Chimiques*\*.

Butter is the third principle contained in milk. It is separated from the scum and the caseous matter by rapid agitation. The substance called cream is a mixture of cheese and butter which floats on the top of the milk: Violent agitation converts this into froth; in which state it is called *whipped cream*.

Butter has a soft consistence, is of a yellow golden colour more or less deep, of a mild agreeable flavour, melts easily, and becomes solid again by mere cooling.

Butter is easily changed, and becomes rancid like oils: The acid which is developed may be carried off by water, or by spirit of wine, which dissolve it. Fixed alkali dissolves butter, and forms a soap little known.

Distillation affords a coloured concrete oil from butter, and a strong pungent acid. This oil, by repeated distillation, becomes altered, and resembles volatile oils.

Milk is therefore a mixture of oil, lymph, serum, and salt: This mixture is weakly united, and the union between the principles is easily destroyed. Milk is said to be *turned* when the disunion of its principles is effected by mere repose; but when this separation is made by re-agents, it is said to be *curdled*† or coagulated.

### CHAPTER III.

#### Concerning the Blood,

**BLOOD** is that red humour which circulates in the human body by means of the arteries and veins, and supports life by supplying all the organs with the peculiar

\* It is in the fourth volume of the *Annales de Chimie* that the author has inserted an extract from his excellent Memoir on this subject. T.

† *Lait tourné* and *lait caillé*. This distinction scarcely obtains in the English language. T.

juices they demand. It is this humour which receives the product of digestion from the stomach, which it elaborates and animalizes. This humour is with reason considered as the focus of life. The difference of temperaments with regard to the passions, has been attributed to it by all the philosophers who have treated this subject. It is in vain that physicians have changed their system; for the opinions of the people have been less versatile, and they have continued to attribute all the shades of temperament to the modifications of the blood. It is likewise to the alterations of this humour that physicians have for a long time ascribed the cause of almost every malady. It is more especially entitled to the attention of the chemist.

The blood varies in the same individual, not only with regard to the state of health, but likewise at the same instant. The blood which circulates through the veins has not the same intensity of colour, nor the same consistence, as that of the arteries; that which flows through the organs of the breast differs from that which passes languidly through the viscera of the lower belly.

The blood differs also—1. According to the age. In infancy it is paler and less consistent. 2. According to the temperament. Sanguine persons have the blood of a vermilion red; in the phlegmatic it is paler; and in the choleric it is more yellow.

The temperature of the blood is not the same in the several species of animals. Some have the blood hotter, and some colder, than the medium in which they live. Animals with lungs have the blood redder and hotter than those which are without that organ; and the colour and heat are in proportion to the extent and perfection of the lungs, as M. Buffon and Broussonet have observed.

The blood putrefies by a gentle heat. If it be distilled on the water-bath, it affords phlegm of a faint smell, which easily putrefies. Blood dried by a proper heat, effervesces with acids; if exposed to the air, it attracts humidity; and at the end of several months a saline efflorescence is formed, which Rouelle has ascertained to be soda. If the distillation of blood be carried farther, the product is acid, oil, carbonate of ammoniac, &c. A spongy coal remains in the retort,



of very difficult incineration, in which are found sea salt, carbonate of soda, iron, and phosphate of lime.

Alcohol and the acids coagulate the blood; alkalis render it more fluid.

But if the blood received in a shallow basin be observed, the following alterations are seen:—It first becomes divided into two very distinct substances, the one liquid, slightly greenish, and called lymph, or serum; and the other reddish and solid, called the fibrous part of the blood. It is this separation of the blood which has caused the existence of polypi in the larger vessels to be credited, because concretions have been found in those vessels after death. We will separately examine these two substances.

Serum has a yellow colour, inclining to green. Its taste is slightly saline. It contains a disengaged alkali, turns syrup of violets green, and hardens in a moderate heat, which is the character of the lymph. Serum distilled on a water-bath affords an insipid phlegm, neither acid nor alkaline, but very readily putrefying. When this phlegm has passed over, the residue is transparent like horn, no longer soluble in water, and affording by distillation an alkaline phlegm, carbonate of ammoniac, and a fetid blackish oil more or less thick; the remaining coal in the retort is very voluminous, and very difficult to incinerate; the ashes afford muriate of soda and phosphate of lime.

Serum easily putrefies, and then affords much carbonate of ammoniac.

Serum poured into boiling water coagulates; but it contains a part which is soluble in water, to which it communicates a milky colour, and all the properties of milk, according to Bucquet.

Alkalis render the serum more fluid, but acids coagulate it. By filtering and evaporating the fluid, a neutral salt is obtained, consisting of the acid employed, and soda. It appears therefore that the lymph is kept in the liquid state by the predominating alkali.

The thickened serum affords mephitic by the nitric acid, assisted by a slight heat; if the fire be increased, nitrous gas is disengaged: the residue affords the oxalic acid, and a portion of malic acid.

Serum is coagulated by alcohol; but the coagulum is soluble in water, and in this it differs much from the coagulum



formed by acids: this difference depends on the circumstance that the alcohol seizes the water which diluted the serum; whereas the acid seizes the alkali which dissolved it.

The clot or fibrous part of the blood likewise contains much lymph; but this may be disengaged by washing. The water at the same time carries off the colouring matter, which contains much iron; and this coagulated part, when well washed, forms a fibrous white substance void of smell; which, distilled on the water-bath, affords an insipid phlegm, easily susceptible of putrefaction. The residue becomes very dry, even by a gentle heat; when suddenly exposed to a considerable heat, it shrinks up like parchment; but when distilled in a retort it affords an alkaline phlegm, carbonate of ammoniac, oil, &c. The coal, which is less voluminous and lighter than that of lymph, affords the phosphate of lime by incineration.

The fibrous part putrefies with considerable quickness, and affords much ammoniac.

The alkalis do not dissolve it, but acids combine with it. The nitric acid disengages much nitrogene, and afterwards dissolves it with effervescence, and disengagement of nitrous gas. The residue affords oxalic acid, and a small quantity of the malic acid.

This fibrous substance is of the nature of the muscular fibre, which caused Borden to call the blood fluid flesh: and long before the time of this celebrated physician, Paul Zacchia asserted that "*caro nihil aliud est quam sanguis concretus*" (*Quest. Legalis*, p. 239). This fibrous matter is more animalized than the lymph; and it appears to be prepared by the very act of circulation to concur in augmenting the parts of the human body.

Blood contains much iron. The experiments of Menghini, Buequet, and Lorry, prove that this metal is capable of passing into the blood by the first passages, since patients who are under a course of martial medicine void it by the way of urine. When the coagulated part of the blood has been washed, if that part which has retained the colouring matter be burned, and the coal lixiviated, the residue of this lixivium is in the state of saffron of mars, of a fine colour, and usually obedient to the magnet.

The colour of blood has been attributed to iron; and it is very true that the colour appears to be entirely formed of it, for there exists no vestige of this metal in the washed and discoloured coagulum: but as, on the other hand, the blood does not become coloured without the concurrence of air, and as oxigene alone is absorbed in respiration, it appears that the colour is owing to iron calcined by the pure air, and reduced to the state of red oxide.

From this manner of conceiving the phenomenon, we may perceive why animal substances are so advantageous in assisting and facilitating the red dye, and why these substances take colours more easily.

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#### CHAPTER IV.

##### Concerning Fat.

**FAT** is a condensed inflammable juice contained in the cellular membrane: its colour is usually white, but sometimes yellow; its taste insipid; and its consistence more or less firm, in the various species of animals. In cetaceous and other fish, it is nearly fluid; in carnivorous animals the fat is more fluid than in frugivorous animals, according to Mr. De Fourcroy. In the same animal it is more solid near the kidneys, and under the skin, than in the vicinity of the moveable viscera; as the animal grows old, the fat becomes yellow, and more solid. Consult De Fourcroy. To obtain fat in a state of purity, it is cut into small pieces; the membranes and smaller vessels are separated; it is washed, then fused with a small quantity of water, and kept in fusion until all the water is evaporated. This last fluid which floats above it, boils; and when the ebullition ceases, it is a proof that all the water is dissipated.

Fat has the greatest analogy with oils. Like them it is not miscible with water; it forms soaps with alkalis; and burns in the open air, by the contact of an ignited substance, at a sufficient heat.

Neumann treated the fat of the goose, of the hog, of the sheep and of the ox, in a glass retort by a graduated fire. He obtained phlegm, an empyreumatic and brownish oil, and a brilliant

coal. He concludes from his analysis that there is little difference between fats; and that that of the ox appears only to contain a little more earthy matter. This very imperfect analysis throws no light on the nature of fat; and we are indebted to Messrs. Segner and Crell for experiments of a much more interesting kind. We shall relate the chief.

1. Beef suit distilled on the water-bath, in a glass retort, affords oil and phlegm; it forms soaps with potash: the reddish phlegm has an acid taste; effervesces with alkali, without reddening the syrup of violets, which assumes a brown colour by this mixture.

2. The marrow of beef affords the same products, excepting that a substance first passes over of the consistence of butter. The phlegm has no smell when cold. Fixed alkali occasions a weak effervescence.

Mr. Crell has instructed us in the means of obtaining a peculiar acid from fat, which is at present distinguished by the name of the Sebacic Acid.

He at first attempted to concentrate this acid by distilling off the phlegm; but this did not succeed, for the liquid in the receiver was as acid as that in the retort. He then saturated all the acid with potash, and obtained a brownish salt by evaporation, which he fused in a crucible, to burn the oil which contaminated it. This salt, by solution and evaporation, afforded a foliated salt. He poured four ounces of sulphuric acid upon ten ounces of the salt, and distilled by a very gentle fire. The sebacic acid passed over in the form of a greyish vapour; and half an ounce, very fuming and acrid, was found in the receiver. Crell observes that, in order to succeed in this operation, the salt must be kept a long time in fusion, without which the acid would be mixed with oil, which weakens its virtue.

By distillation of fat in a copper alembic, Mr. Crell obtained the pure acid. But the fire necessary for this purpose alters the vessel, causes the tin to run off, and the acid itself becomes charged with copper.

It has long been known that the alkalis form a kind of soap with animal fat. Mr. Crell, by treating this soap with a solution of alum, separated the oil, and obtained the sebate of potash by evaporation: the sulphuric acid afterwards distilled from this salt, decomposes it; and by this means the sebacic acid is separated.



Mr. De Morveau melted suet in an iron pot; and to this he added pulverized quicklime, taking care to stir it continually at the commencement; at the end of the operation, a considerable heat was applied, taking care to raise the vessels, in order to avoid exposure to the vapours. When the whole was cold, it was found that the suet had no longer the same solidity. This was boiled in a large quantity of water; and the lixivium, after filtration, afforded a brown acrid salt, which is the sebate of lime. This salt is soluble in water, but would require too much time to purify it by repeated crystallizations. This purpose is more easily answered by exposing it to a degree of heat capable of burning the oil; after which, a single solution is sufficient to purify it. It leaves its oil upon the filtre in the state of coal; and nothing more is then necessary than to evaporate it.

The solution usually contains a small quantity of quicklime, which may be precipitated by the carbonic acid. This salt, treated in the same manner as the sebate of potash, affords the sebacid acid.

This acid exists ready formed in suet: two pounds afforded somewhat more than seven ounces to Crell. It exists ready formed in the fat, since earths and alkalis disengage it.

It has the greatest affinity with the muriatic acid, as it forms with potash a salt which melts in the fire without being decomposed; it acts powerfully on gold; when mixed with the nitric acid; it precipitates silver from the nitrate of silver; it forms a sublimate with mercury, and the solution of this sublimate is not rendered turbid by the muriate of soda. But though this acid approaches the muriate in several respects, it differs from it in others, and hitherto seems to be nothing but a modification of that acid. With soda, it forms crystals in needles, and a crystallized salt with lime. It decomposes common salt, &c.

Mr. Crell obtained the acid of fat by distillation from the butter of cacao. Spermaceti likewise affords it.

The properties of this acid are the following:

It reddens blue vegetable colours.

It assumes a yellow colour by fire, and leaves a residue, which announces a partial decomposition. From this circumstance, Mr. Crell considers it as occupying the middle space between the vegetable acids which are destroyed by



fire, and the mineral which receive no alteration. Its existence in the butter of cacao, and in fats, is favourable to the notion of Crell on this subject.

It attacks the carbonates of lime and alkali with effervescence, and with them forms salts which Bergmann finds to be very similar to the acetites with the same basis.

This acid, as Mr. De Morveau observes, seems to have some action upon glass. Mr. Crell having digested it several times upon gold, always obtained a precipitate of white earth, which was not lime, but which he presumes to have been carried up in the distillation, and could only arise from the retort itself.

This acid does not perceptibly act on gold: but it attacks the oxide, and forms a crystallizable salt, as it does likewise with the precipitates of platina.

It unites with mercury and with silver; yielding the latter to the muriatic acid, but not the former: it takes both from the sulphuric acid, lead from the nitric and acetic acids, and tin from the nitro-muriatic acid.

It attacks neither bismuth, cobalt, nor nickel.

It does not decompose the sulphates of copper, of iron, or of zinc; nor the nitrates of arsenic, manganese, zinc, &c.

It reduces the oxide of arsenic by distillation. Crell formed a sebatic ether.

From this analysis it appears that fat is a kind of oil or butter rendered concrete by an acid.

Its uses are—1. To keep up the heat of the body, and defend the viscera from the impression of external cold. 2. To serve as nourishment or support for the animal on the occasions of want, sickness, &c.

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## CHAPTER V.

### Concerning the Bile.

**T**HE Bile is one of those humours which it is essential to know, on account of the influence and effect it has both in the states of health and disorder. We shall even see that its analysis is sufficiently perfect to afford instruction in an infinity of cases.

This humour is separated in a large viscus of the lower belly, called the Liver; it is afterwards deposited in a bladder, or reservoir, called the Gall Bladder; from which it is conveyed into the duodenum by a particular channel.

The bile is glutinous, or imperfectly fluid, like oil; of a very bitter taste; a green colour, inclining to yellow; and froths by agitation like the solution of soap.

If it be distilled on the water-bath, it affords a phlegm, which is neither acid nor alkaline, but putrefies. This phlegm, according to the observation of Mr. De Fourcroy, often emits a smell resembling that of musk: bile itself has the same property, according to the general observation of butchers. When the bile has given out all the water it is capable of affording upon the water-bath, the residue is a dry extract, which attracts the humidity of the air, is tenacious, pitchy, and soluble in water. By distillation in a retort, it affords ammoniac, an empyreumatic animal oil, concrete alkali, and inflammable air. The coal is more easily incinerated than that we have last treated of. It contains iron, carbonate of soda, and phosphate of lime.

All the acids decompose bile; and disengage an oily substance, which rises to the top. The salts afterwards obtained by evaporation, have soda for their basis; which shews that the bile is a true animal soap. The oil which is combined with soda is analogous to resins, is soluble in spirit of wine, &c.

The metallic solutions decompose bile by double affinity, and produce metallic soaps.

Bile unites with oils, and cleans stuffs in the same manner as soap.

Bile is soluble in alcohol, which separates the albuminous principle. It is this last substance which renders bile coagulable by fire and by acids; and it is this likewise which hastens its putrefaction.

The constituent principles of bile are, water, a spiritus rector, a lymphatic substance, a resinous oil, and soda. Mr. Cadet has found a salt in it, which he thought similar to sugar of milk; this salt is probably no other than that which was discovered by Mr. Poulletier.

Bile is therefore a soap, resulting from the combination of soda with a matter of the nature of resins, and a lymphatic

substance, which renders it susceptible of putrefaction and coagulation. This substance gives the bile the character of animalization, diminishes its acridity, and favours its mixture with the other humours. The saline part renders the bile more fluid and soluble in water; and it is more acrid the more this principle abounds.

The resinous part differs from vegetable resins—1. Because these do not form soap with fixed alkalis. 2. Because they are more acrid and more inflammable. 3. Because the animal resin melts at the temperature of 40 degrees, and acquires a fluidity similar to that of fat; from which however it differs in not being soluble in alcohol, in which respect it approaches to spermaceti.

The acids which act upon bile in the first passages, decompose it. The greenish yellow colour of the excrements of infants at the breast, arises from a similar decomposition; and it is the resinous part which tinges them. From the action of the bile upon acids, we may deduce the effect of these remedies when the evacuations are putrid, and the degeneration of the bile is septic. The lymph is then coagulated, and the excrements become harder. This shews the reason why the excrements of infants are so frequently clotted.

When the bile remains a long time in the first passages, as for example in chronical disorders, it assumes a black colour, becomes thick, acquires the consistence of an unguent, and forms a lining of several lines in thickness in the intestinal canal, according to the observation of Mr. De Fourcroy. When smeared on paper, and dried, it becomes green; diluted with water, it forms a tincture of a yellow green colour, from which a large quantity of black scales are precipitated: with alcohol it likewise forms a black tincture, and deposits that laminated brilliant salt discovered in biliary calculi by Mr. Poulletier de la Salle. This humour, which forms the *atra bilis* of the ancients, is nothing but the bile rendered thick; and in this case the effect of acids, and the danger of irritating substances, may be easily accounted for. This thickening of the bile clogs the viscera of the lower belly, and produces obstructions.

Many disorders are referable to the predominant character of the bile. On this subject, the interesting Memoirs of



Mr. De Fourcroy may be consulted, in the collection of the Royal Society of Medicine for the years 1782 and 1783.

When the bile becomes thick in the gall bladder, it forms the concretions called biliary calculi. Mr. Poulletier has paid great attention to the analysis of these stones. He has observed that they are soluble in ardent spirit. When the solution is left to itself for a certain time, brilliant and light particles are seen in it, which Mr. Poulletier found only in the human calculi, and which appeared to him to have the greatest analogy with the salt of benzoin.

Mr. Fourcroy has observed that the discovery of Mr. De la Salle has been confirmed by the Royal Society (of Medicine), which has received several biliary calculi that appeared to be formed by a salt analogous to that which was observed by this chemist. They consist of masses of transparent crystalline plates, similar to mica or talc. The Society of Medicine possesses in its collection a gall bladder entirely filled with this saline concretion.

We may therefore, as Mr. De Fourcroy observes, admit of two kinds of calculi: the one are opaque, and are afforded only by the condensed bile; the others consist of the crystals we have described.

Boerhaave observed, long since, that the gall bladder of oxen, at the end of the winter, was filled with calculi, but that the fresh pasturage dissipated these concretions.

Soaps have been proposed as solvents for these calculi. The Academy of Dijon has published the success of a mixture of essence of turpentine and ether. Fresh vegetables, which are such sovereign remedies in destroying these concretions, owe their virtue perhaps to the circumstance that they develop an acid in the stomach, as we have observed in treating of the gastric juice.

The use of the bile, in the animal œconomy, consists, no doubt, in dividing those substances which have undergone a first digestion in the stomach; and in giving efficacy and force to the motion of the intestines. When its flux is interrupted, it abounds in the blood, and the whole body becomes of a yellow tinge.

The bile or gall is an excellent vulnerary externally applied: internally taken, is a good stomachic, and one of the best deobstruents the art of medicine possesses. This



kind of remedies deserves the preference, as being more analogous to the constitution; and bile is a proper medicine when the digestion languishes, or the viscera of the lower belly are clogged.

Bile, like other soaps, removes spots of oil, or other greasy matter, from substances to which they are adherent.

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## CHAPTER VI.

Concerning the Soft and White Parts of Animals.

THESE parts are perhaps less known than those of which we have just treated; but their analysis is not less interesting: we may even affirm that it is more so; because the application of the knowledge we may acquire on this subject, will daily present itself in the commonest purposes of domestic life.

All the parts of animals, whether membranes, tendons, aponeuroses, cartilages, ligaments, or even the skin and horns, contain a mucous substance very soluble in water, but not in alcohol, and known by the name of Jelly. Nothing need be done to obtain it, but to boil these animal substances in water, and concentrate the decoction, until by mere cooling it assumes the form of a solid tremulous mass.

Jellies are very common in our kitchens: and the cooks are perfectly well acquainted with the methods of making them, and of giving them solidity when the temperature of the atmosphere is very hot. The jelly of harts-horn is extracted by a similar operation, and afterwards rendered white with the milk of almonds. This kind of food, duly scented, is served up at our tables by the name of *blanc manger*. Jellies are in general restorative and nourishing: that of harts-horn is astringent and emollient.

Jellies in general have no smell in their natural state, and their taste is insipid. By distillation they afford an insipid and inodorous phlegm, which easily putrefies. A stronger heat causes them to swell up, become black and emit a fetid odour accompanied with white acrid fumes. An alkaline phlegm then passes over, succeeded by an empyreumatic oil, and a little carbonate of ammoniac. A spongy coal remains

which is with difficulty reduced to ashes, and affords by analysis muriate of soda and phosphate of lime.

Jelly cannot be kept above a day in the summer, or two or three in the winter. When it becomes spoiled, white livid spots are formed on its surface, which speedily extend to the bottom of the pots. A large quantity of nitrogenous, hydrogenous, and carbonic gas is emitted.

Water dissolves jellies perfectly. Hot water dissolves a large quantity, as they become consistent only by cooling. Acids likewise dissolve them, and alkalis more especially do.

The nitric acid disengages nitrogene gas, according to the fine experiments of M. Berthollet.

When jelly has been extracted without long decoction, and has no lymph mixed with it, it then possesses most of the characters of the vegetable jelly: but it is seldom obtained without a mixture of lymph; and in this case it essentially differs from the vegetable jellies, in affording nitrogene gas and ammoniac.

If jelly be concentrated to such a degree as to give it the form of a cake, it is deprived of the property of putrefying; and by this means the dry or portable soups are formed, which may be of the greatest advantage in long voyages. The following is a receipt for preparing these cakes:

Calves feet	4
Leg of beef	12 pounds.
Knuckle of veal	3 pounds.
Leg of mutton	10 pounds.

These are to be boiled in a sufficient quantity of water, and the scum taken off as usual; after which the soup is to be separated from the meat by straining and pressure. The meat is then to be boiled a second time in other water; and the two decoctions, being added together, must be left to cool, in order that the fat may be exactly separated. The soup must then be clarified with five or six whites of eggs, and a sufficient quantity of common salt added. The liquor is then strained through flannel, and evaporated on the water-bath to the consistence of a very thick paste; after which it is spread rather thin upon a smooth stone, then cut into cakes, and lastly dried in a stove until it becomes brittle: these cakes are kept in well closed bottles. The same pro-

cess may be used to make a portable soup of the flesh of poultry; and aromatic herbs may be used as a seasoning, if thought proper.

These tablets or cakes may be kept four or five years. When intended to be used, the quantity of half an ounce is put into a large glass of boiling water, which is to be covered, and set upon hot ashes for a quarter of an hour, or until the whole is entirely dissolved. It forms an excellent soup, and requires no addition but a small quantity of salt.

The cakes of hockiac, which are prepared in China, and are known in France by the name of *colle de peau d'âne*, are made with animal substances. They are used in disorders of the lungs, in the dose from half a dram to two drams.

The nature of the substances made use of, and the method of operating, produce some difference in these products. Old or lean animals afford in general a better glue than the young and fat. For a full account of the art of making glue, consult *L'Art de faire différentes Espèces de Colle, par M. Duhamel de Monceau, de l'Académie des Sciences*.

1. To make the strong or English glue, the parings of leather, the skins of animals, with the ears of oxen, calves, sheep, &c. are used. These matters are first digested in water, to penetrate the texture of the skins; they are afterwards steeped in lime water, taking care to stir and agitate them from time to time; they are then laid in a heap for some time, afterwards washed, and the superabundant water pressed out by a press. These skins are then digested in water gradually heated to ebullition. The liquor is afterwards poured out, and separated with pressure. Lastly, it is thickened by evaporation of the water by heat, and poured on flat polished stones or into moulds, and left to dry and harden.

This glue is brittle. It is softened by heating it with a small quantity of water for use, and is applied with a brush. Carpenters and cabinet-makers use it to fasten pieces of wood together.

2. The glue of Flanders is merely a diminutive of the strong glue. It has not the same consistence, and cannot be used in glueing wood; it is thinner and more transparent than the former. It is made with a more accurate choice of materials, and with greater care. It is used by designers.



Mouth glue is made of this, to stick paper together, by fusing it again with the addition of a small quantity of water, and four ounces of sugar-candy to a pound of the glue.

3. The colle de gand is made with the clippings of white gloves, well steeped in water, and boiled: it is likewise made with the clippings of parchment. In order that these two kinds of glue may be fit for use, it is necessary that they be of the consistence of a tremulous jelly when cold\*.

4. Fish-glue, or isinglass, is made of the mucilaginous parts of a large fish commonly found in the Russian seas. The skin, the fins, and the nervous parts, are cut into slices, boiled on a slow fire to the consistence of jelly, spread out to the thickness of a sheet of paper, and formed into cakes or long pieces, such as we receive them from Holland. The silk manufacturers, and more especially the ribbon weavers, use it to give a lustre to their goods: it is also used to stiffen gauzes; and to clarify or fine wine, by mixing a solution of this substance with it. Isinglass enters into the composition of some plasters. It is excellent to correct acrid humours, and terminate obstinate venereal disorders.

Gilders size is made by boiling eel-skins in water with a small quantity of lime: the water is strained off, and some whites of eggs added. When it is intended to be used, it is heated, applied to the surface intended to be gilded, and when it is dry the gold leaf is laid on.

5. The glue of snails is made by exposing snails to the sun, and receiving in a glass the fluid which flows from them. This liquor is mixed with the juice of milk thistle. It is used to cement glasses together, which are afterwards exposed to the sun to dry.

6. To make the glue of parchment, or parchment size, two or three pounds of the clippings of parchment are put into a pail of water. These are boiled until half the water is evaporated; after which the whole is strained through a cloth, and left to settle.

The glue or size used in the paper manufactories, to fortify the paper, and to repair its defects, is made with wheat flour diffused in boiling water, and strained through a sieve. This size must be used the following day, and neither sooner nor

\* These weaker glues are called Size by our workmen, who apply the name of Glue to the strong glue only. T.



later. The paper is afterwards beat with a mallet, sized a second time, put into the press to smooth and unite it; and afterwards extended by hammering.

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## CHAPTER VII.

Concerning the Muscular or Flešhy Parts.

THE muscles of animals are formed of longitudinal fibres connected together by the cellular membrane, and impregnated with various humours, in which we find partly those we have already examined separately.

The analysis of these substances by distillation afforded us little instruction respecting their nature. The products were, water which easily became putrid, alkaline phlegm, empyreumatic oil, carbonate of ammoniac, and a coal which afforded by incineration a small quantity of fixed alkali, and febrifuge salt.

The process which succeeds the best for separately obtaining the various substances which compose muscles, is the following, which has been pointed out to us by Mr. De Fourcroy.

1. The muscle is first washed in cold water: by this means the colouring lymph, and a saline substance, are taken up. By slow evaporation of this water, the lymph coagulates, and may be separated by the filtre; and a continuance of the evaporation affords the saline matter.

2. The residue of the first washing is digested in alcohol, which dissolves the extractive matter, and a portion of the salt; the extract is separated by the evaporation of the alcohol.

3. The residue of these first operations is to be boiled in water, which takes up the jelly, the fat part, and the remaining saline and extractive matters. The fat oil swims on the surface, and may be taken off.

4. After these operations, there remains only a white infixed fibrous substance, insoluble in water; which contracts by heat, like other animal substances; affords ammoniac, and very fetid oil, by distillation. Nitroge gas is obtained from it by the nitric acid. It possesses all the characters

of the fibrous part of the blood, in which fluid it is formed, to be afterwards deposited in the muscles, where it receives the last character appropriated to it.

Mr. Thouvenel, to whom we are indebted for interesting researches on this subject, has found in flesh a mucous extractive substance, soluble in water and in alcohol, possessing a peculiar taste which jelly has not; and when this substance is very much concentrated, it assumes an acrid and bitter taste. Fire developes an aromatic flavour in it. This substance, evaporated to dryness, assumes a bitter, acrid, and saline taste. It swells up upon hot coals, and liquefies; emitting an acid, penetrating smell, resembling that of burned sugar. It attracts the humidity of the air, and forms a saline efflorescence. In a hot atmosphere it becomes sour, and putrefies. All these characters indicate a resemblance between this substance, the saponaceous extracts, and the saccharine matter of vegetables. Mr. Thouvenel, who has likewise analysed the salt obtained by the decoction and slow evaporation of flesh, obtained it sometimes in the form of down, and sometimes in that of crystals, whose figure he could not describe. This salt appeared to him to be a phosphate of potash in frugivorous quadrupeds, and a muriate of potash in carnivorous reptiles. It is probable, as Mr. De Fourcroy observes, that this salt is a phosphate of soda or of ammoniac, mixed with the phosphate of lime. These salts are indicated, and even with excess of acid, like those of urine, by lime-water and ammoniac, which form white precipitates in the decoction of flesh.

The most abundant part of muscles, and that which constitutes their predominating character, is the fibrous matter. The characters which distinguish this substance are—

1. It is not soluble in water.
2. It affords more nitrogenous gas by the nitric acid than other substances do.
3. It afterwards affords the oxalic acid, and the malic acid.
4. It putrefies easily when moistened, and affords much concrete ammoniac by distillation.

The other three substances contained in flesh, namely the lymph, the jelly, and the fat part, are the same substances concerning which we have already treated, under the same denominations.

From these principles we may give the ethiology of the formation of soup, and follow the successive disengagement of all the principles we have spoken of.

The first impression of the fire, when a soup is made, is the disengagement of a considerable scum, which is taken off until it no longer appears. This scum arises merely from the disengagement of the lymph, which coagulates by the heat. It assumes, by the impression of the fire, a red colour, which it does not naturally possess.

At the same time the gelatinous part is disengaged, which remains dissolved in the soup, and congeals only by cooling. It forms on the surface of cold soup a body more or less thick, according to the nature of the substances, and the age of the animals; for young animals afford a larger quantity than such as are old.

As soon as the flesh is penetrated by heat, flat round drops arise, and float at the surface of the fluid, in which they are not afterwards dissolved, but congeal by cooling, and exhibit all the characters of fat.

In proportion as the digestion proceeds, the mucous extractive part separates; the soup becomes coloured, assumes its peculiar odour and taste; and it is more particularly to this principle that its properties are owing.

The salt which is at the same time dissolved takes off the insipidity of all the before-mentioned principles: and at this period the soup is completely made.

According to the nature of the several principles which are disengaged, and the order in which they appear, it is evident that the management of the fire is not a matter of indifference. If the ebullition be hastened, and a proper time be not allowed for the disengagement of the mucous extractive matter, the three inodorous and insipid principles are obtained; and this is observed in soups made by cooks who are hastened, or have not time allowed to pay a due attention to their work. When, on the contrary, the digestion is made over a slow fire, the principles separate one after the other, in order; the skimming is more accurately performed; the aromatic flavour which is disengaged combines more intimately, and the soup is of an excellent flavour. These are the soups of the good women who perform better with a

small quantity of meat, then professed cooks with their usual prodigality, and in this case we may say that the form is of more value than the substance.

The heat must not be applied too long; for the great evaporation, by concentrating the principle of smell and taste, at the same time with the salt, renders them acrid and bitter.

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## CHAPTER VIII.

### Concerning Urine.

URINE is an excrementitious humour of the body: and it is one of the fluids of which it is of the greatest importance to possess an accurate knowledge; because the practical physician may derive the greatest advantage from information of this nature. It is known to what a degree of extravagance the marvellous pretensions of this kind have been carried. The delirium has proceeded to such a height, as even to pretend to ascertain from the urine, not only the nature of the disorder, and the character of the patient, but likewise the sex and condition.

The true physician has never given into this excess: but he has always derived assistance, in his practice, from the characters exhibited by the urine; and this is the humour from which he may draw the most satisfactory indications. It carries out, as we may say, the internal character; and a physician who knows how to form a judgement upon its properties, may deduce the most instructive consequences from it. *Monro*, in his *Treatise of Comparative Anatomy*, has described the organs which, in birds, supply the place of the kidneys: they are placed near the vertebral column; and communicate, by two ducts, to the vicinity of the anus. He affirms that the urine of birds is that whitish substance which almost always accompanies the excrements.

Chemical analysis ought to enlighten the physician in his researches concerning the Urine. The nature of the principles it carries off in certain circumstances, affords vast information respecting the predominant principle in the fluids of the human body. Its various states shew the disposition of the constitution. Persons of a very irritable habit have the



urine of a lighter colour than others; gouty persons evacuate turbid urine; and it has been observed that, when the bones become soft, the urine carries off the phosphate of lime, which constitutes their basis; instances of which were observed in the persons of Mrs. Supiot, the widow Melin, &c. The various states of any disorder are always pointed out by the state of the urine; and the truly practical physician will there observe signs of crudity and concoction which will direct his proceedings.

Urine is likewise an humour interesting to be known on account of the various uses to which it is applied in the arts. It was from this substance alone that phosphorus was, for a long time, extracted; it is to this fluid that we owe the development of the blue colour of turnsole, and the violet of archil; it may be successfully employed in forming artificial nitre-beds; it powerfully contributes to the formation of sal ammoniac; it may be used to prepare the alkali in the manufacture of Prussian blue; and, in a word, it may be applied in all the operations wherein the concurrence of an animal humour is required.

Urine, in its natural state, is transparent, of a citron yellow colour, a peculiar smell, and a saline taste.

It is more or less abundant, according to the seasons, and the state of the individual. It is sufficient to observe, on this subject, that transpiration, and more especially perspiration or sweat, supply the place of the secretion of urine; and that consequently, when the transpiration is great, the urine is not abundant.

Physicians distinguish two kinds of urine. The one is emitted one or two hours after drinking; this is aqueous, contains scarcely any salts, and has neither colour nor smell: it is this which is evacuated so plentifully during a course of mineral waters. The other is not evacuated until after the functions of sanguification are finished; and may be called *Fæces Sanguinis*. This has all the characters we have enumerated and assigned to urine. It is carried by the arteries into the kidneys, where it is separated, and poured into the receptacles of these organs, whence it passes, by the ureters, into the bladder; where it remains a longer or shorter time according to the habitude of the person, the nature of the urine, the irritability or magnitude of the bladder itself.

The urine has been long considered as an alkaline fluid ; but in our time it has been proved to contain an excess of acid. It appears from the experiments of M. Berthollett—

1. That this acid is of the nature of the phosphoric acid.
2. That the urine of gouty persons contains less of this acid ; whence he conjectures, with reason, that this acid retained in the blood, and conveyed into the articulations, produces an irritation, and consequently a flux of humours, which cause pain and swelling.

The analysis of urine by distillation has been accurately made by various chemists, but more especially by Rouelle the younger. Much phlegm is obtained, which putrefies with the greatest facility, and affords ammoniac by its putrefaction, though it does not itself contain that substance. At the same time a substance is precipitated of an earthy appearance, but which in reality is a true phosphate of urine. It is this same salt which forms the sediment of urine, which is observed by exposing it to cold during the winter, even though the urine be of a person in perfect health. When urine has, by a sufficient evaporation, acquired the consistence of syrup, it need only be exposed, in a cool place, to obtain crystals, in which analysis has proved the existence of the phosphates of soda and of ammoniac. This precipitate of crystals has been distinguished by the name of fusible salt, native salt, microcosmic salt. Urine may be deprived of all saline matter by repeated solutions, filtrations, and evaporations ; the matter which adheres to these crystals, and of which they may be cleared by these operations, is soluble, partly in alcohol and partly in water. The saponaceous substance, or that which is soluble in alcohol, is capable of crystallization, dries difficultly, and affords by distillation a small quantity of oil, of carbonate of ammoniac, of muriate of ammoniac, and the residue converts syrup of violets to a green. The extractive principle is easily dried, and exhibits the same phenomena in distillation as animal substances. See Rouelle.

The phenomena exhibited by the spontaneous decomposition of urine, are very interesting to be known ; on which subject an excellent memoir of Mr. Halle in the volume of the Society of Medicine for 1779, may be consulted. Urine left to itself soon loses its smell, which is succeeded by a smell of ammoniac, which is likewise dissipated in its turn.

The colour becomes brownish, and the smell fetid and nauseous. We are indebted to Mr. Rouelle for a valuable observation—that crude urine, *urina potius*, presents very different phenomena; and that it becomes covered with mouldiness, like the expressed juices of vegetables. Putrefied urine has much less acid in the disengaged state than when it is fresh.

The fixed alkalis and lime disengage much ammoniac from urine by decomposing the phosphate of ammoniac.

The acids destroy the smell of urine by combining with the ammoniac, which is the principal vehicle of that smell.

We may therefore consider urine, in its natural state, as water holding in solution matters purely extractive, and phosphoric or muriatic salts. These phosphoric salts have lime, ammoniac, or soda, for their basis: we shall take a slight view of each in particular.

That which is called fusible salt, is nothing but a mixture of all the salts contained in urine, clogged with the extractive principle. All the ancient chemists advised evaporation and repeated filtration, to clear them from this animal extract; but Messrs. Rouelle and the Duke de Chaulnes have observed, that great part of the salt is disengaged and dissipated by these operations to such a degree, that three-fourths are lost. To avoid most of this loss, the Duke de Chaulnes advises solution, filtration, and cooling in well-closed vessels. Two strata of salt are then obtained; the upper of which appears to have the form of square tables, wherein Rouelle observed tetrahedral prisms flattened with dihedral summits. This is the phosphate of soda: and beneath this lies another salt crystallized in regular tetrahedral prisms, and is the phosphate of ammoniac.

1. The phosphate of ammoniac usually exhibits the form of a very compressed tetrahedral rhomboidal prism: but this form varies much; and the mixtures of the phosphate or muriate of soda cause an infinity of modifications in it.

The taste of this salt is cool, afterwards urinous, bitter and pungent.

This salt swells up upon the coals, emits a strong smell of ammoniac, and melts by the blow-pipe into a very fixed and very fusible glass.

It is soluble in water. Five parts of cold water, at ten degrees of Reaumur, dissolved only one of this salt; but at the temperature of sixty degrees this salt is decomposed, and a portion of its acid is volatilized.

It serves as a flux to all the earths; but in this case its alkali is disengaged, and the phosphoric acid unites with the earth, as I find by experiment. Bergman proposed it as a flux. The fixed alkalis and lime-water disengage the ammoniac.

When this salt is heated with charcoal, it affords phosphorus.

2. The phosphate of soda was made known in 1740 by Haupt, under the name of *sal admirabile perlatum*. Hellot before him, and Pott seventeen years after him, took it for selenite. Margraff gave an accurate description of it in his *Memoirs*, in 1745; and Rouelle the younger described it at full length in 1776, under the name of fusible salt with base of natrum. All agree that it differs from the preceding in not affording phosphorus with charcoal.

According to Rouelle, its crystals are flattened irregular tetrahedral prisms, with dihedral summits. The four sides of the prism are two irregular alternate pentagons, and two long rhombi truncated slopewise.

When exposed to heat it fuses, and affords a glass which becomes opake by cooling.

It is soluble in distilled water, and the solution turns syrup of violets green.

It does not afford phosphorus with charcoal.

Lime disengages the soda. It may even be obtained in a caustic state, if the precipitation be effected by lime-water.

The mineral acids, or even distilled vinegar, decompose it by seizing its alkali. Mr. Proust, to whom we are indebted for all the accurate information we possess concerning these substances was of opinion, that the base to which the soda adhered was not the phosphoric acid, but a very singular salt, whose properties greatly resembled those of the acid of borax. He found this salt in the mother water, after having decomposed the phosphate of soda by the acetous acid, and obtained the acetite of soda by crystallization. He obtained this same salt by dissolving and evaporating the residue of the distillation of phospho-



rus. One ounce of phosphoric glass contains five or six drams. This salt was characterized by the following properties:

1. It crystallizes in parallelograms.
2. Its taste is alkaline, and it turns syrup of violets green.
3. It swells up in the fire, reddens, and melts.
4. It effloresces in the air. This may not take place when the phosphoric acid has not been sufficiently decomposed by the distillation to leave the alkali disengaged, as I have observed.
5. Boiling water dissolves six gros per ounce.
6. It assists the vitrification of earths, and forms a perfect glass with silica.
7. It decomposes nitre and marine salt, and separates their acids.
8. It is insoluble in alcohol.

Mr. Klaproth has published in *Crell's Journal* an analysis of the fusible salt, in which he has shewn that the pearly salt, or salt of Proust, is merely the phosphate of soda. To prove this, nothing more need to be done than to dissolve this salt in water, and to add a solution of nitrate of lime. The nitric acid seizes the soda, and the phosphoric acid is precipitated with the lime. The phosphoric acid may afterwards be separated by means of the sulphuric acid.

If the phosphoric acid obtained by the slow combustion of phosphorus be saturated with soda slightly in excess, the fusible salt is formed; if this excess be taken up by vinegar, or if more phosphoric acid be added, the substance described by Proust is formed.

The phosphate of soda is not decomposable by charcoal; and it is at present clearly seen why the fusible salt affords but little phosphorus; and why Künckel, Margraaf, and others recommended a mixture of the muriate of lead: for by this means the phosphate of lead was formed, which permits the decomposition of the phosphoric acid, and affords phosphorus.

#### Concerning the Calculus of the Bladder.

Paracelsus made some researches concerning the calculus of the bladder, which he calls *duelech*. He considers it as a substance intermediate between tartar and stone, and thinks

that its formation is owing to the modification of an animal resin: he supposes it to be absolutely similar to the matter of the gout.

Vanhelmont does not admit of this analogy; and considers the calculus as an animal coagulum produced by the salts of urine, and a volatile earthy spirit. Boyle found this calculus to be composed of oil and volatile salt. Boerhaave supposed it to consist of a subtle earth, intimately united with alkaline volatile salts. Hales has observed that a calculus of the weight of two hundred and thirty grains afforded six hundred and forty-five times its volume of air, and that there remained only a calx of the weight of forty-nine grains.

Independent of this chemical information, some physicians, such as Allston, De Haen, Vogel, Meckel, &c. had observed the solvent power of soap, lime-water, and alkalis.

But we possessed no accurate ideas on this subject until it was seriously taken up by Scheele and Bergmann. The bezoar of the bladder is formed for the most part of a peculiar concrete acid, which M. De Morveau calls the Lithiatic Acid. (The *Encyclopedie Methodique* may be consulted, from which the present article is an extract.)

The calculus is partly soluble in boiling water. The lixivium reddens the tincture of turnsole; and by cooling deposits most of what it had dissolved. The crystals thus separated are the concrete lithiatic acid.

Scheele has likewise observed—1. That the sulphuric does not dissolve the calculus unless assisted by heat, and that it is then converted into the state of sulphureous acid: 2. That the muriatic acid has no action upon it. 3. That the nitric acid dissolves it with effervescence, and disengages nitrous gas and carbonic acid. This solution is red; it contains a disengaged acid, and tinges the skin of a red colour. This solution is not precipitated by the muriate of barytes; nor rendered turbid by the oxalic acid. 4. That the calculus was not attacked by the carbonate of potash; but that the caustic alkali dissolved it, as well as the volatile alkali. 5. That one thousand grains of lime-water dissolved 5,37 by mere digestion, and that it was again precipitated by acids: 6. That all urine, even that of infants, held a small quantity of the matter of calculus in solution; which may perhaps be

the cause that, when this matter finds a nucleus in the bladder, it more easily encrusts it. I have seen a calculus with a large plum stone in its centre. 7. That the brick-coloured deposition from the urine in fevers, is of the nature of the calculi.

These experiments exhibit several important consequences with regard to the composition of the calculus, and the properties of the lithic acid.

The calculus contains a small quantity of ammoniac. The coaly residue of the combustion indicates an animal substance of the nature of jelly. The celebrated Scheele did not find it to contain a particle of calcareous earth; but Bergmann precipitated a true sulphate of lime, by pouring the sulphuric acid into the nitrous solution of the calculus. He admits that the lime is very small in quantity, as it rarely exceeds the two-hundredth part of the entire weight. The same chemist has detected a white spongy substance, not soluble in water, nor attacked by spirit of wine, or acids, or alkalis; which at last affords a coal of difficult incineration, and which the nitric acid does not dissolve, even in the state of ashes; but this matter exists in so small a quantity, that he could not procure enough to examine it. The calculus is not therefore analogous to bones in its nature; neither is it a phosphate of lime, as has been pretended. These are the results of the chemists of the north; but I must observe that, after having decomposed many calculi by the caustic alkali, I have precipitated lime, and formed phosphates of potash.

Some physicians, such as Sydenham, Cheyne, Murray, &c. have thought that the arthritic concretions were of the same nature as the calculus. The use of which Boerhaave made of alkalis in the gout; the virtues admitted by Fred. Hoffmann in the thermal waters of Carlsbad, which contain soda, with an excess of carbonic acid; the authority of Springfield, who asserts that the calculus is very speedily dissolved in these waters, even in the urine of those who drink them; the success of lime-water, used by Alston in the gout—all conspire to give some credit to the opinion of these early physicians. But the following experiments do not agree with this notion.

Vanfwieten affirms that the arthritic concretion never acquires the harshness of the calculus. Pinelli (*Philos. Trans.*) distilled in a retort three ounces of the arthritic matter collected from the articulations of several gouty persons; and he obtained ammoniac, with some drops of oil, the residue weighing two gros. This residue, which was soluble in the muriatic, sulphuric, and acetous acids, was not attacked by volatile alkali. An observation of Mr. Røering was published in the *Memoirs of the Academy of Stockholm* for 1783, which ascertains that the concretions expectorated by an old man subject to the gout, were found to be of the nature of bone, or phosphate of lime. But one of the newest and most important facts is that of Watson, in the *Medical Communications of London*, vol. i. 1784. He concludes, from the examination of the arthritic concretions of a gouty body, that this substance is very different from the matter of the calculus, since it is soluble in the synovia, and easily mixes with oil and water, which the calculus does not.

It follows from our observations on the lithic acid, that this acid is concrete, and sparingly soluble in water; that it is decomposed, and partly sublimed by distillation. This acid decomposes the nitric acid, unites with earths, alkalis, and metallic oxides. It yields its bases to the weakest vegetable acids, not excepting the carbonic.

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## CHAPTER IX.

### Concerning Phosphorus.

**P**HOSPHORUS is one of the most astonishing products of chemistry. It is pretended that traces of the knowledge of this substance exist in the writings of the earliest chemists: but the most positive information we possess on this subject is found in the history given by Leibnitz, in the *Melanges de Berlin* for 1710. He gives the discovery to Brandt, a chemist of Hamburg, who during a course of experiments upon urine, with a view of extracting a fluid proper to convert silver into gold, discovered phosphorus in the year 1667. He communicated his discovery to Kraft, who shewed it to Leibnitz; and being afterwards in England, he



communicated it to Boyle\*. Leibnitz caused the first inventor to be introduced to the Duke of Hanover, before whom he performed the whole operation; and a specimen of the phosphorus was sent to Huygens, who shewed it to the Academy of Sciences at Paris.

It is said that Kunckel had associated himself with Kraft to purchase the process from Brandt. But Kunckel having been deceived by Kraft, who kept the secret to himself, knowing that urine was made use of, set to work, and discovered a process for making the substance; and it is this which led chemists to call it by the name of Kunckel's Phosphorus.

Though the process was rendered public, Kunckel, and a German called Godefred Hatwith†, were the only persons who prepared phosphorus for a long time. It was not till the year 1737, that it was made in the laboratory of the Royal Garden at Paris. A foreigner executed this operation in the presence of Messrs. Hellot, Du Fay, Geoffroi, and Du Hamel. An account of the operation may be seen in the volume of the Academy for 1737. Hellot has collected all the essential circumstances. Margraaf, in the year 1743, published a new and more easy method, which has been followed until Scheele and Gahn taught us to obtain it from bones.

\* As Boyle communicated the process for making phosphorus to the Royal Society as a discovery of his own, and it is entered as such in the Philosophical Transactions, I cannot avoid animadverting on this impeachment of his integrity, which is copied from one chemical book into another. It is grounded on no better foundation than the assertion of Kraft, a dealer in secrets, who, after having deceived his friend Kunckel, associated with him for the purchase of this secret. I might insist, in defence of the candour and otherwise unimpeached integrity of Boyle, that his assertion ought infinitely to outweigh that of the other. Not to insist, however, upon this, it may be noticed that this new and famous product was known to have been extracted from urine; that Kunckel is universally admitted as the discoverer, from his having formed it upon no fuller information than this; that Boyle might with equal probability be admitted to have discovered it in the same manner, and upon information equally slight; and that the probability of this is rendered incomparably greater, by the consideration that none of these chemists made any complicated experiments, but merely applied the force of fire to urine until this product at last came over. T.

† Spelled Hanckwitz by most authors. He was instructed by Boyle. T.

The process of Margraaf consists in mixing the muriate of lead, which remains after the distillation of four pounds of minium and two of sal ammoniac, with ten pounds of the extract of urine of the consistence of honey. Half a pound of charcoal in powder is added; the mixture is dried in an iron pot until it is reduced to a black powder. This powder is to be put into a retort; and the volatile alkali, the fetid oil, and the sal ammoniac, distilled off. The residue contains the phosphorus. It is assayed by throwing a small quantity on hot coals: if it emits a smell of garlic, and a phosphoric flame, it is to be put into a good earthen retort, and distilled. Much more phosphorus is obtained by this than by the old process; and this depends on the addition of the muriate of lead by Margraaf, which decomposes the phosphate of soda, forming a phosphate of lead, which affords phosphorus; whereas the phosphate of soda is not decomposable by charcoal. The famous chemist of Berlin has likewise proved that it was the fusible salt of urine which affords the phosphorus.

Mr. Gahn published, in the year 1769, that the earth of calcined bones consisted of lime united with the acid of urine; but Scheele was the first to prove that by decomposing this salt of bones by the nitric and sulphuric acids, evaporating the residue in which the phosphoric acid exists in a disengaged state, and distilling the extract with powder of charcoal, phosphorus is obtained. These circumstances, related by Bergmann himself in his notes to the Chemistry of Scheffer, attribute to Scheele the discovery of extracting phosphorus from bones. It was not until the year 1775 that the process was published in the *Gazette Salulaire de Bouillon*. Additions and improvements have been successively made in this process, of which accounts may be seen in the *Dictionnaire Encyclopedique*.

The process which has most constantly succeeded with me, is the following:

The hardest bones are selected and burned. By this combustion the external part becomes white, while the internal part is blackish.

These burned bones must then be pulverized, and put into a turine, or in a round hooped wooden vessel. Half their weight of oil of vitriol is then to be poured on, and constant-

ly stirred. During the agitation a considerable heat is excited. The mixture must be left in digestion for two or three days; after which, water must be gradually added, and stirred. I digest this last mixture upon the fire, in order to encrease the solvent power of the water.

The water of the lixivium is then to be evaporated in vessels of stone ware, silver, or copper. Mr. Pelletier recommends this last metal; because, according to him, the phosphoric acid does not attack copper. The evaporation must be carried to dryness; more boiling water must be poured on the residue; and this washing must be continued until the matter be exhausted, which may be known by the water being no longer tinged yellow. All these waters are to be evaporated, and afford an extract.

To separate the sulphate of lime, the extract must be dissolved in the least possible quantity of water, then filtered, and the salt remains on the filtre. This extract may be mixed with powder of charcoal, and distilled: but I prefer converting it into animal glass; for which purpose I put the extract into a large crucible, and urge the fire. It swells up at first, but at last settles; and at that instant the glass is made. This glass is white, of a milky colour. Becher was perfectly acquainted with it; but concealed his process, on account of the abuses which, according to him, might be made of it—*propter varios abusos*. He tells us, in proper terms, *homo vitrum est, et in vitrum redigi potest, sicut et omnia animalia*. He regrets that the Scythians, who drank out of disgusting sculls, were not acquainted with the art of converting them into glass. He shews that it would be possible to form a series of one's ancestors in glass, in the same manner as we possess them in painting, &c.

I observed once, to my great astonishment, that the phosphoric glass I had just made, emitted very strong electric sparks: these flew to the hand at the distance of two inches. I exhibited this phenomenon to my audience of pupils. This glass lost the property in two or three days, though preserved in a capsule of common glass.

It sometimes happens that this glass is deliquescent, but it is then acid; and this circumstance arises from too large a quantity of sulphuric acid, or from this acid not having been saturated by a digestion of sufficient continuance.

I have likewise obtained glass of the colour of turquoise, when I performed the evaporation in copper vessels.

This glass may be deprived of the bubbles it usually contains, by keeping it for a time in a violent heat; it is then transparent, and may be cut like a diamond. According to Crell, its specific gravity is to that of water as three to one, while that of diamond is as three and a half to one. This glass is insoluble in water, &c. A skeleton of nineteen pounds, burned, affords five pounds of phosphoric glass.

I pulverize this glass, mix it with equal parts of powder of charcoal, put it into a porcelain retort well coated, the beak of which I partly plunge into the water of the receiver, so that nothing can escape but air or phosphoric gas. I adapt a large tube to the tubulure of the receiver, and plunge it into a vessel filled with water. The fire being raised by degrees, the phosphorus comes over the moment the mixture is ignited. The phosphorus sublimes, partly in the form of a fume which congeals; and is precipitated upon the surface of the water, partly in the form of inflammable gas, and partly resembling melted wax, which drops in beautiful transparent tears from the neck of the retort. The theory of this operation is easily explained. The phosphoric acid is displaced by the sulphuric acid, as is shewn by the large quantity of sulphate of lime which is obtained. All the other operations tend only to concentrate this phosphoric acid, which is still combined with other animal substances, and the distillation with charcoal decomposes the phosphoric acid; its oxygen unites with the coal, and affords a carbonic acid, while the phosphorus itself becomes disengaged.

To purify the phosphorus, a piece of chamois leather is moistened, and the mass of phosphorus is put into it. This being immersed in a vessel of boiling water, the phosphorus melts, and is passed through the skin like mercury. The skin cannot be used more than once; the phosphorus, which might be passed a second time, would become coloured. This process was contrived by Mr. Pelletier.

In order to form phosphorus into sticks, a funnel with a long neck may be used, the lower orifice being closed with a small cork, or piece of soft wood. The funnel is then to be filled with water, and phosphorus put in it; and this being plunged in boiling water, the heat is communicated to that



of the funnel; and melts the phosphorus, which runs into the neck, and takes that form. The funnel is then removed into a vessel of cold water; and when the phosphorus is perfectly cooled, the cork is taken out, and the phosphorus thrust out of its mould with a small piece of wood.

Phosphorus is kept under water. After a certain time it loses its transparency, becomes covered with a white powder, and the water is acidulated\*.

In whatever manner phosphorus may be made, it is always one and the same substance, characterized by the following properties:—It is of a flesh colour, and evidently transparent. It has the consistence of wax; and may be cut in pieces with a knife, or twisted asunder with the fingers; in which last case the precaution must be taken of frequently plunging it into water, to prevent its taking fire.

When phosphorus is placed in contact with the air, it emits a white fume. It is luminous in the dark; and a solid stick of phosphorus may be used to write with, like a crayon. The marks are visible in the dark; and this means has often been used to create fear and astonishment in the minds of the ignorant.

When phosphorus is exposed to twenty-four† degrees of heat, it takes fire with decrepitation, burns with a very bright flame, and emits a very abundant white fume which is luminous in the dark. The residue of the combustion is a red caustic substance, which attracts the humidity of the air, and becomes resolved into a liquor. This is the phosphoric acid, which we shall proceed to treat of.

Mr. Wilson affirms that the solar rays set fire to phosphorus; and proves that this flame has the colour proper to the

\* This slow acidification of the phosphorus seems to be reversed by the sun's light. Sticks of phosphorus, which had become covered with a white powder, were exposed under water to the sun's light, which converted them to an orange yellow colour in such parts as were acted upon by the direct light. This fact appears to be of the same nature as the colouring of the nitrous acid, and other similar phenomena. T.

† Twenty-four degrees of Reaumur answer to eighty-six of Fahrenheit. The vivid combustion of phosphorus takes place at different temperatures, according to its purity; but the present is very low. By taking phosphorus into a freezing atmosphere, its faint flame disappears, and it seems to require a temperature of sixty degrees to revive it. I found the vivid combustion to take place at one hundred and sixty degrees. T.

phosphorus, and not that of the ray itself.—Letter of Mr. Wilson to Mr. Euler, read at the Royal Society of London in June 1779.

An advantageous use has lately been made of the combustible property of phosphorus, to procure fire conveniently, and in all situations, by means of phosphoric tapers or matches, and the philosophical bottles, the method of making which we shall point out.

1. The most simple process for making the phosphoric matches, consists in taking a glass tube, four inches long and one line in diameter, closed at one end. A small quantity of phosphorus is introduced into the tube, and pushed to its further end; after which a taper covered with a small quantity of wax is introduced into the same tube. The open end is then hermetically sealed, and the other end is plunged into boiling water. The phosphorus melts, and fixes itself upon the match.

A line is drawn at one third of the length of the tube, with a flint, that it may be broken as occasion may require.

The match is to be drawn out quickly, to inflame the phosphorus.

The process of Mr. Lewis Peyla, to make the inflammable bougies, consists in taking a glass tube, five inches long and two lines wide, one end of which is sealed with the blow-pipe. Small tapers of wax are prepared with three double threads of cotton twisted together. The extremity of the match or taper is half an inch long, and must not be covered with wax.

A piece of lead is laid in a saucer filled with water; and upon this the phosphorus is cut, beneath the water, into fragments of the size of a grain of millet. One of these grains is to be dried, and introduced into the tube of glass; after which the fortieth part of a grain of very dry sulphur is to be added, that is to say, half the weight of the phosphorus. One of the bougies is then taken, and its extremity dipped in very clear oil of wax. If too large a quantity rises, it must be dried with a cloth.

The match is introduced into the tube with a turning or twisting motion between the fingers.

The bottom of the tube must then be plunged in boiling water, to soften the phosphorus; observing to keep it no longer than three or four seconds in the water.

The other extremity of the tube is afterwards sealed.

These bougies must be kept in a tin tube, to avoid the danger of inflammation.

2. To form the phosphoric bottles, a glass bottle is heated by fixing it in a ladle full of sand, and two or three small pieces of phosphorus are then introduced into it. A small red-hot iron wire, is used to stir the phosphorus about, and cause it to adhere to the internal surface of the bottle, where it forms a reddish coating. The heated wire is introduced repeatedly; and when all the phosphorus is thus distributed within the bottle, it is left open for a quarter of an hour, and afterwards corked. When this is used, a common match tipped with sulphur is introduced into the bottle, turned round, and quickly drawn out. The phosphorus which sticks to the sulphur takes fire, and lights the match.

The theory of this phenomenon depends on the circumstance that the phosphorus is strongly dried, or half calcined, and needs only the contact of air to set it on fire.

Phosphorus is soluble in oils, more especially the volatile oils, which then become luminous. If this solution be kept in a bottle, a phosphoric flash, which emits a small quantity of light, will be seen every time the bottle is opened. The oil of cloves is used in this operation. The combination of phosphorus and oil appears to exist naturally in the glow-worm, *lampyris splendidula* Linnæi. Forster of Gottingen observes, that the shining matter of the glow-worm is liquid. If the glow-worm be crushed between the fingers, the phosphorescence remains on the finger. Henckel reports, in the eighth dissertation of his *Pyritologia*, that one of his friends, of a sanguine temperament, after having danced much, perspired to such a degree that he thought his life in danger. While he undressed, traces of phosphoric flame were seen on his shirt, which left yellow red spots behind them, resembling the residue of burned phosphorus: this light was long visible.

A phosphoric gas may be extracted from phosphorus, which takes fire by the mere contact of the air. Mr. Gengembre has shewn the method of extracting it, by digesting alkalis upon it (Memoir read to the Academy at Paris the 3d of May 1783); and at the same time I shewed that it

might be extracted by means of acids, which are decomposed upon phosphorus. I have likewise taken notice, in my Memoir upon the decomposition of the nitric acid by phosphorus, that when the acid is digested upon it, a gas escapes, which takes fire in the receiver, and has several times afforded me the appearance of flashes of lightning striking through the cavity of the vessels. But this phenomenon disappeared as soon as the vital air was absorbed.

It is to the disengagement of a gas of this nature that we may attribute the *ignes fatui* which play about burying grounds, and generally in all places where animals are buried and putrefy. It is to a similar gas that we may refer the inflammable air which constantly burns in certain places, and upon the surface of certain cold springs.

Phosphorus is found in the three kingdoms. Mr. Gahn found the phosphoric acid in lead. Siderite is a phosphorus of iron. The seeds of rocket, of mustard, of garden cresses, and of wheat, treated by Margraaf, afforded him a fine phosphorus. Mr. Meyer of Stetin has announced, in the Chemical Annals of Crell for the year 1784, that the green resinous part of the leaves of plants contains the phosphoric acid. Mr. Pilatre du Rozier renewed the opinion of Rouelle in 1780 (*Journal de Physique* for November), who considered the phosphoric acid as analogous to that of mucilaginous bodies; and he affirms that the distillation of pyrophorus affords five or six grains of phosphorus in the ounce. The phosphoric acid exists in urine, bones, horns, &c. M. Maret, by treating twelve ounces of beef by combustion, obtained three gros of transparent phosphoric glass. M. Crell obtained it from beef suet and human fat; M. Hankwitz from excrements; Leidenfrost from old cheese; Fontana from fishes bones; Berniard from egg shells, &c. Messrs. Macquer and M. Struve found the phosphoric acid in the gastric juice.

The most interesting combination of phosphorus is that which it forms with vital air. This is always the phosphoric acid; but the acid appears to be modified by the manner in which it is made.

Phosphorus unites with oxigene—1. By desflagration, or the rapid combustion. 2. By the slow combustion. 3. In the humid way, more especially by the decomposition of the nitric acid.



1. If phosphorus be exposed to a dry heat of twenty-four degrees, it takes fire, emits a white dense fume, and leaves a reddish residue, which powerfully attracts the humidity of the air, and becomes resolved into a liquor. This combustion may be performed under glass vessels; in which case white flocks are deposited on the sides of the glass, which resolve into a liquor by the contact of moist air, and form the phosphoric acid. Care is taken to introduce an additional quantity of vital air when the combustion of the phosphorus has not been completed.

M. Lavoisier has burned phosphorus, by the assistance of a burning glass, under a glass vessel plunged in mercury (Memoirs of the Royal Academy of Sciences, 1777.)

Margraaf had observed that air is absorbed in this operation. M. Morveau, in the year 1772, had declared the same from his own experiments; and Fontana proved that phosphorus absorbs and vitiates air, like every other combustible substance. Mess. Lavoisier and De la Place found that forty-five grains of phosphorus absorbed 65,62 of vital air.

The acid obtained by this means is impure. It always contains phosphorus in solution, not saturated with oxigene.

2. Phosphorus is most completely decomposed by the slow combustion. For this purpose the neck of a glass funnel is inserted into a bottle, and sticks of phosphorus are disposed round in the funnel, so as not to touch each other; a small piece of glass tube being put into the neck, to prevent their falling through. A paper is tied over the funnel. The phosphorus is slowly decomposed; and, as it becomes converted into a fluid, it flows into the bottle, where it forms a liquid without smell or colour. This acid almost always retains a small quantity of undecomposed phosphorus, from which it may be cleared by digesting alcohol upon it, which dissolves the phosphorus without volatilizing the acid.

One ounce of phosphorus produces in this manner three ounces of phosphoric acid.

3. The nitric acid may be decomposed by digestion upon phosphorus. The nitrous gas is dissipated; and the oxigene remains united to the phosphorus, with which it forms phosphoric acid. When the nitric acid is very concentrated, the phosphorus takes fire, and burns at its surface. I published this process, with all the circumstances of the opera-

tion, in 1780, the same year in which the excellent Memoir of M. Lavoisier on the same question was printed, and of which I had then no knowledge.

The water in which phosphorus is kept, contracts acidity in the course of time; which shews that the water itself is decomposed, and yields its oxigene to the phosphorus.

Phosphorus precipitates some metallic oxides from their solutions in the metallic state. It is observed that acid is formed in this operation; which proves that the oxigene quits the metal to unite with the phosphorus.

The phosphoric acid is clear, inodorous, without being corrosive. It may be concentrated to dryness. Crell having concentrated it to dryness, found its specific gravity, compared with water, to be as 3. 1.

This acid is very fixed. If it be concentrated in a matrafs, the water is first dissipated, a smell of garlic is soon perceived, which arises from a portion of phosphorus, from which this acid is difficultly cleared: and vapours likewise rise. The liquor becomes turbid, assumes a milky appearance, and a pasty consistence; and if the matter be put into a crucible, on hot coals, it boils considerably. The vapour which issues renders the flame green; and the mass at last becomes converted into a white transparent glass, insoluble in water.

The phosphoric acid has no action on quartz.

It dissolves clay with ebullition.

It dissolves barytes; and unites to clay with singular facility, with which it forms a salt of sparing solubility. The solution, when well charged, lets fall, at the end of four-and-twenty hours, crystals in small thin flattened needles, several lines long, and obliquely truncated at each end. The phosphoric acid precipitates lime from lime-water, and forms a true phosphate of lime, very similar to the basis of bones, and decomposable by the mineral acids like that substance.

The phosphoric acid, saturated with potash, forms a very soluble salt, which affords tetrahedral crystals terminating in tetrahedral pyramids. This phosphate is acid, swells up on hot coals, and is difficult of fusion. Lime-water decomposes it.

Soda, combined with the phosphoric acid, affords a salt of a taste resembling that of the muriate of soda. This phosphate does not crystallize, but becomes converted into a

gummy and deliquescent mass by evaporation. M. Sage affirms that phosphate of soda prepared with the acid of the slow combustion, forms a salt susceptible of crystallization.

Dr. George Pearson has combined the phosphoric acid obtained by nitric acid with soda, and obtained a neutral salt in rhomboids.

This salt, though saturated, turns syrup of violets green, effloresces in the air, and has a saline taste resembling that of common salt. It purges in the dose from six to eight drams, without producing either nausea or griping, and has not a disagreeable taste.

The phosphoric acid acts only on a small number of metallic substances. On this subject the works of Mess. Margraaf and De Morveau may be consulted.

The phosphoric acid has a very evident action on oils. Mixed with an equal portion of olive oil, it acquires a fawn colour by mere agitation, which subsists even after the separation. This shade increases if the two fluids be digested together; the acid becomes thick; and the oil which floats above becomes black and coaly, and emits a strong smell.

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## CHAPTER X.

Concerning certain Substances obtained from Animals for the Use of Medicine and the Arts.

**T**HERE is not perhaps any animal product whose virtues have not been celebrated by some of the physicians; and there are few animals which have not at some time or other been mentioned as contributing to the advantage of medicine. Time however has happily condemned to oblivion those productions which ought never to have possessed celebrity: and we shall accordingly, on the present occasion, attend only to such as experience has shewn to possess the virtues and powers attributed to them.

We shall not therefore treat of the lungs of the fox, the liver of the wolf, the feet of the elk, the jaws of the carp, the nests of the swallow, the powder of the toad, the dung of the peacock, the heart of the viper, the fat of the badger, nor even that of the hanged malefactor.



Various quadrupeds, cetaceous animals, birds, and fishes, afford products in which chemical and medical experience has ascertained very evident virtues.

## ARTICLE I.

Concerning the Products afforded by Quadrupeds.

Under this article we shall treat of the products most in use which are extracted from quadrupeds. These are castoreum, musk, and hartshorn.

1. The name of Castoreum is given to an unctuous fluid contained in two pouches situated in the inguinal region of the male or female castor. An accurate description of it may be seen in the Encyclopedic. This very odorant substance is soft, and nearly fluid when recently extracted from the animal; but it dries in the course of time. It has an acrid, bitter, and nauseous taste; and its smell is strong, aromatic, and even stinking.

Alcohol dissolves a resin which colours it; water extracts an abundant principle. By evaporation of the water a salt is obtained, the nature of which is little known. Castoreum affords by distillation a small quantity of volatile oil, ammoniac, &c.

The uses of castor in the œconomy of the animal are unknown. The ancients had the credulity to believe that the creature itself took it when its stomach was weak.

It is used in medicine as a powerful antispasmodic, in the dose of a few grains in substance; and it enters as a component part into boluses, extracts, &c. It is advantageously joined with opium; and its spirituous tincture is also prescribed in suitable liquids, in a dose from twenty-four to thirty-six drops.

We see clearly, from the little chemical information we possess respecting this substance, that it is a resin joined with a mucilage, and a salt which facilitates the union of its principles.

2. The name of Musk is given to a perfume obtained from various animals. In 1726 an animal was received, under the name of the Musk Animal, in the Royal Menagerie, which came from Africa, and resembled the civet. Mr. Perreault has left a description of it. It was supported six years upon raw flesh. M. De la Peyronnie gave a very good description of it to the Academy of Sciences for the year 1731.



The organ which contained the musk was situated near the genital parts (it was a female). At the aperture of the bag which contained the musk the smell was so strong, that M. De la Peyronnie could not inspect it without inconvenience. This liquor is prepared by two glands, which transmit it into the common reservoir through a number of small perforations.

The other animal which affords musk in the East, is of the class of squirrels. It is very common in Chinese Tartary. It carries the musk in a bag beneath the navel. This bag, projecting outwards of the size of a pullet's egg, is formed of a membranous and muscular substance, provided with a sphincter. Many glands are observable within, which separate the humour. As soon as the beast is killed, this bladder is cut off and tied up: but its contents are adulterated with the testicles, the blood, and other offals of the animal; for each creature affords no more than three or four gros. Musk must be chosen soft, unctuous, and odorant; and ought to be consumed totally upon hot coals. The musk of Tonquin, which is most esteemed, is contained in bags covered with brown hair; but that of Bengal is covered with white hair.

Musk contains nearly the same principles as castoreum. The smell of pure and unmixed musk is too strong and oppressive. It is rendered mild by mixture with other substances. It is little used in medicine; is a powerful antispasmodic in some cases; but ought to be administered with caution, because it often excites nervous affections instead of calming them.

The smell of musk predominates in certain animals. M. De la Peyronnie knew a man from whose left arm-pit there was emitted so strong a smell of musk during the summer, that he was obliged to weaken it to avoid inconvenience.

3. Hartshorn affords several products which are much employed in medicine. The preference is given to this horn because it contains less earthy salt than bones; but all kinds of horn may be used indiscriminately.

Hartshorn was formerly calcined with the greatest care, and used as a remedy against alvine fluxes.

The products of hartshorn which are mostly used at present, are those obtained by distillation. An alkaline phlegm

is first obtained, which is called the Volatile Spirit of Hartshorn. Next comes over a reddish oil, more or less empyreumatic; and a very great quantity of carbonate of ammoniac, soiled and coloured by the empyreumatic oil. The oil which colours the salt may be disengaged by means of spirit of wine, which dissolves it. The coaly residue contains natrum, sulphate, and phosphate of lime, from which phosphorus may be obtained by the processes already described.

The spirit and the salt obtained from hartshorn are used in medicine as good antispasmodics.

The oil duly rectified forms the animal oil of Dippel. As the highest virtues have been attributed to this substance, a thousand methods have been attempted to purify it. For a long time it was usual to rectify it a great number of times, in order to have it white and fluid. But Mess. Model and Baume have advised taking only the first portion which comes over, because this is the most attenuated, and the whitest. Rouelle advises distillation with water; and as the most volatile part only rises with the heat of boiling water, there is a certainty of having it very fine by this means. For my part, I distil the empyreumatic oil with the earth of Murviel, which retains all the colouring part; and by this means I have it at once white and attenuated.

This is odorant, and has all the properties of the volatile oils: but it turns syrup of violets green, as Mr. Parmentier has observed; which proves that it retains a small quantity of volatile alkali. This oil is used in doses of a few drops in nervous affections, epilepsy, &c. It is used externally, by rubbing it on the skin, as a sedative, and to remove obstructions; but the great virtues formerly attributed to it are not much credited at present.

## ARTICLE II.

Concerning certain Products afforded by Fishes.

The oil of fish, and spermaceti, are the most used among the products obtained from fishes.

Spermaceti is a concrete oil extracted from the cacholot. The name of Sperma-ceti is very improper. These animals are of a prodigious size, and afford large quantities of this matter. Plomet relates that in 1688 a Spanish ship took a

Whale whose head afforded twenty-four barrels of brains, and the body ninety-six barrels of fat. This spermaceti is always mixed with a certain quantity of inconcrescible oil, which is carefully removed.

Spermaceti burns with a very white flame. It is made into candles at Bayonne and at St. Jean de Luz. These candles are of a shining white colour, become yellow in process of time, but not so soon as wax and the dense oils.

If it be distilled on a naked fire, it does not afford an acid phlegm, but rises totally, at the same time that it assumes a reddish tinge. Several repeated distillations deprive it of its natural consistence.

The sulphuric acid dissolves it; and this solution is precipitated like the oil of camphor. The nitric and muriatic acids have no action upon it.

Caustic alkali dissolves spermaceti, and forms a soap which gradually acquires solidity.

Alcohol dissolves spermaceti by the assistance of heat, but lets it fall as it cools. Ether likewise dissolves it.

The fixed and volatile oils dissolve it by the assistance of heat.

This substance was formerly much used. It was given as an emollient, and softening remedy; but at present it is almost forsaken, and not without cause; for it is heavy, insipid, and nauseous.

The egg, the scales, and the black fluid of the cuttle fish are still used in medicine. The eggs deterge the kidneys, and excite urine and the courses. The scales and bones of the cuttle-fish are applied to nearly the same uses: they are likewise used as an astringent; and enter into dentifrice powders, collyria, &c. The goldsmiths likewise use them to make their moulds for casting spoons, forks, toys, &c. because its spongy part easily receives the impression of metals. The black humour of the cuttle-fish, which is found in a bag near the cœcum, and of which Mr. Le Cat has given a description, may be used instead of ink. We read in the Satires of Persius that the Romans used it as an ink; and Cicero calls it *Atramentum*. It seems that the Chinese use it as the basis of their famous ink. "*Sepia piscis est qui habet succum nigerrimum, instar atramenti, quem Chineses cum brodio orizæ, vel alterius leguminis, inspissant et formant, et*

in universum orbem transmittunt, sub nomine Atramenti Chinenfis" (Pauli Hermani Cynosura, t. i. p. 17, par. 2). Pliny was of opinion that the black humour of the cuttle-fish was its blood. Rondelet has proved that it is the bile. This is the fluid the cuttle-fish disgorges when in danger: a very small quantity is sufficient to blacken a large quantity of water.

Calcined oyster shells are likewise used in medicine as an absorbent.

The oil extracted from fish is of the greatest use in the arts.

### ARTICLE III.

Concerning certain Products afforded by Birds.

Most of the birds are used at our tables as a delicate food, but few afford any medical products. The eagle stones, to which so much virtue had been attributed for facilitating labours, the plasters of swallows nests, and other similar substances, have all fallen into neglect, as the natural consequence of the observation of matter of fact being substituted in the place of credulity and superstition. The analysis of eggs begins to be known. They consist of four parts: an osseous covering, called the shell; a membrane which covers the constituent parts of the egg; the white; and the yolk, which occupies the centre.

The shell, like bones, contains a gelatinous principle, and the phosphate of lime.

The white is of the same nature as the serum of blood. It renders syrup of violets green, and contains uncombined chalk; heat coagulates it; by distillation it affords a phlegm which easily putrefies; it becomes dry like horn; and carbonate of ammoniac, and empyreumatic oil, come over. A coal remains in the retort, which affords soda, and phosphate of lime. M. Deyeux has also obtained sulphur by sublimation.

Acids and alcohol coagulate it.

If it be exposed to the air in thin leaves, it dries, and becomes consistent; and it is on this property that the custom is founded of passing the white of egg over the surface of paintings, to give them that brightness which is produced by varnish, and also to defend them from the air. The drying



may be hastened by quick-lime; and this mixture affords a lute of the greatest tenacity.

The yolk of egg likewise contains a lymphatic substance, mixed with a certain quantity of mild oil, which on account of this mixture is soluble in water. It is this animal emulsion which is known in France by the name of *lait de poule*. Yolk of egg exposed to the fire assumes a consistence less hard than the white. If it be bruised, it appears to have scarcely any consistence; and if it be subjected to the press, it gives out the oil it contains. This oil is very emollient, and is used externally as a liniment. There is the greatest analogy between the eggs of animals and the seeds of vegetables; since both contain an oil rendered soluble in water by the admixture of a glutinous substance.

The yolk of egg renders oils and resins soluble; and this substance is accordingly much used for that purpose.

Calcined egg-shells is an absorbent.

White of egg is successfully used to clarify vegetable juices, whey, liquors, &c. It coagulates by heat; and then rises to the surface of these fluids, carrying with it all the impurities they contain.

#### ARTICLE IV.

Concerning certain Products afforded by Insects.

Millepedes, cantharides, kermes, cochenille, and lac, are the only substances we shall here treat of, because these are not only the most used, but are likewise the best known among the products of insects.

1. Cantharides.—The cantharides are small insects with greenish wings. They are very common in hot countries; and are found on the leaves of the ash, the rose-tree, the poplar, the walnut-tree, the privet, &c.

Cantharides in powder, applied to the epidermis, cause blisters, excite heat in the urine, strangury, thirst, and fever. They produce the same effect taken internally in a small dose. We read in Paré that a courtesan having presented a ragout powdered with cantharides to a young man who supped with her, this unfortunate person was attacked with a priapism, and loss of blood by the anus, of which he died. Boyle affirms that pains at the neck of the bladder have been produced by the handling of cantharides.

We are indebted to Mr. Thouvenel for some information respecting the constituent principles of these insects. Water extracts a very abundant principle, which colours it of a reddish yellow, and also a yellowish oily principle. Ether takes up a green very acrid oil, in which the virtue of the cantharides most eminently resides. So that an ounce of cantharides affords—

				gros.	grains.
Reddish yellow bitter extract	—	—	—	3	0
Yellow oily matter	—	—	—	0	12
Green oily substance, analogous to wax	—	—	—	0	60
Parenchyma, insoluble in water and alcohol	—	—	—	4	0
				8	0

To form a tincture which unites all the properties of cantharides, a mixture must be made of equal parts of water and of alcohol, and the insects digested in it. If this tincture be distilled, the spirit which comes over retains the smell of cantharides.

If spirit of wine alone be used, it takes up merely the caustic part: hence it appears that the virtue of these insects may be increased or diminished according to the exigence of the case.

The tincture of cantharides may be used with success externally, in the dose of two gros, four gros, one or even two ounces, in rheumatic pains, sciatica, wandering gout, &c. It heats the parts; accelerates the circulation; excites evacuations by perspiration, urine, or stool, according to the parts to which it is applied.

Mr. Thouvenel tried upon himself the effect of the green waxy matter. When applied on the skin in the dose of nine grains, it raised a blister full of serosity.

2. The wood-lice, millepedes, aselli, porcelli.—This insect is usually found in moist places, under stones, or beneath the bark of old trees. It avoids the light, and endeavours to conceal itself when discovered. When it is touched, it rolls up in the form of a globe. This insect is used in medicine as an incisive, aperitive, and alterative remedy. It is prescribed either pounded alive, and put into a proper liquid;

or dried and pulverized, in which last form they enter into extracts, pills, &c. The millepedes are given in the dose of fourteen, fifteen, and twenty grains, or more, according to the exigency of the case. Mr. Thouvenel has given us some information concerning the constituent principles of these insects. He obtained by distillation an insipid or alkaline phlegm; the residue afforded an extractive matter, an oily or waxy substance soluble in spirit of wine only, and marine salt with an earthy and an alkaline base.

3. Cochenille.—Cochenille is a substance used in dying scarlet and purple. It is met with in commerce in the form of small grains of a singular figure, mostly convex with little grooves on one side, and concave on the other. The colour of good cochenille is grey mixed with reddish and white. It is at present well determined that it is an insect. Simple inspection with a magnifier sufficiently proves this; and the wings and feet of this insect may be developed by exposing it to the vapour of boiling water, or by digesting it with vinegar. The cochenille is collected in Mexico, upon plants to which the names of Indian Fig, Raquette Nopal, are given. These plants bear fruits which resemble our figs; tinge the urine of those who eat them; and probably communicate to the cochenille the property which makes it useful to the dyer. The Indians of Mexico cultivate the nopal near their habitations, and sow as it were the insect which affords the cochenille. They make small nests of moss or fine herbs, put twelve or fourteen cochenilles into each nest, place three or four of these nests on each leaf of the nopal, and fasten them there by the prickles of the plant: in the course of a few days, thousands of small insects issue out, and fix themselves upon the parts of the leaf which are best sheltered, and afford the most nourishment. The cochenilles are collected several times in the course of the year: and are deprived of life by scalding them, or by putting them into an oven; after which they are dried in the sun. Two kinds of cochenille are distinguished: the one which is produced without culture, and is called Sylvestre; and the other cultivated, which is called Mesteque. This last is preferred. It has been calculated, in the year 1736, that eight hundred and eighty thousand pounds weight of cochenille was annually imported into Europe. Mr. Ellis has

communicated a very good description of the cochenille to the Royal Society of London.

This substance is more especially used in dying : its colour takes readily upon wool ; and the most suitable mordant is the muriate of tin. Mr. Macquer has discovered a method of fixing this colour upon silk, by impregnating the silk with a solution of tin before it is plunged into the bath of cochenille ; instead of mixing a solution in the baths, as is done for woollens.

4. *Kermes*.—*Kermes* is a kind of excrescence, of the size of a juniper-berry, which is greatly employed in medicine and the arts.

The tree which bears it is known by the name of *Quercus Ilex*. It grows in hot countries ; in Spain, Languedoc, Provence, &c. The female of the coccus fixes itself on the plant ; it has no wings, but the male has. When she is fecundated, she becomes large by the developement of her eggs ; she perishes, and the eggs are hatched. It is collected before the developement of the eggs ; for which purpose, the morning is taken, before the heat has acted upon the eggs. The grains are collected and dried, to develope the red colour ; they are then sifted, to separate the powder ; and lastly they are sprinkled with good vinegar, to kill the insect, which would otherwise come forth in a short time.

*Kermes* is much used in the arts : it affords a good red, but less brilliant than that of the cochenille.

A very celebrated syrup of *kermes* is made, by mixing three parts of sugar with one of the grains of *kermes* pulverized. This mixture is kept for a day in a cool place : the sugar during this time unites with the juice of the *kermes* ; and forms with it a liquor which, when drawn off by expression, has the consistence of syrup. The celebrated *confectio alkermes* is made with this syrup.

The grains of *kermes* given in substance, from half a scruple to a gros or dram, are celebrated for preventing abortion.

The grain and the syrup of *kermes* are an excellent stomachic.

5. *Lac*, or *gum-lac*.—This is a kind of wax, collected by red winged ants from flowers in the East-Indies, which they transport to the small branches of the tree where they make



their nests. The nests are full of small cells, in which a red grain is found when the mass is broken. This small grain is, to all appearance, the egg from which the flying ant derives its origin.

Mr. Geoffroy has proved, in a Memoir inserted among those of the Academy for the year 1714, that this must have been a kind of comb, approaching to the honeycomb of bees, the cells of which are formed of a substance analogous to wax\*.

The colouring part of lac may be taken up by water, which, when evaporated, leaves the colouring principle disengaged. It is the fine lake used for dying. Lake is imitated by extracting the colouring principle of certain plants by well-known processes.

## CHAPTER XI.

Concerning some other Acids extracted from the Animal Kingdom.

**I**NDEPENDENT of the acids afforded by the various parts of the human body, which have been separately examined by us, we find acids in most insects. Lister points out one which may be extracted from millepedes (Collect. Acad. tom. ii. p. 303). Mr. Bonnet has observed that the fluid ejected by the great forked-tail caterpillar of the willow, was a true acid, and even very active (Savans Etrangers, tom. ii. p. 276): Bergmann compares it to the most concentrated vinegar. The abbé Boissier de Sauvages has remarked, that in that illness of the silk-worm, which is called muscardin, the humour of the worm is acid. Mr. Chauffier of Dijon obtained an acid from grass-hoppers, from the May-bug, from the lampyris, and several other insects, by digesting them in alcohol. The same chemist has made an interesting course of experiments on the acid of the silk-worm. He gives two methods of extracting it. The first consists in

\* For a description and drawing of the insect which affords the lac, consult Keir in the Philos. Trans. vol. lxxi. p. 374; also Saunders, in the same work, vol. lxxix. for the method of purifying the lac; or a short abridgment of both, in Nicholson's First Principles of Chemistry, p. 490.

bruising the chrysalides, and straining them through a cloth. The fluid which passes is strongly acid; but the acid is weakened by various foreign substances, of which it may be cleared by digestion in spirit of wine. The fluid which passes the filtre after this digestion, is of a fine orange colour. More spirit of wine is to be poured upon it. At every addition of spirit a light whitish precipitate is formed; and the additions of spirit are to be continued until no more precipitate appears.

Instead of bruising the chrysalides they may be infused in spirit of wine, which dissolves all the acid; and as this acid is less volatile than the spirit, this last may be evaporated, and the residue filtered. By these precautions the acid may be cleared of its spirit of wine, and of the mucous matter which was dissolved, but remains on the filtre.

Mr. Chauflier has proved that this acid exists in all the states of the silk-worm, even in the eggs; but that in the egg and in the worm it does not exist in a disengaged state; but combined with a gummy glutinous substance.

The acid of insects which is best known, and upon which most has been written, is the acid of ants, or the formic acid. This acid is so far in a disengaged state, that the transpiration of these animals, and their simple contact without any alteration, proves its existence.

The authors of the fifteenth century had observed, that the flower of chickory thrown into an ant-hill becomes as red as blood.—See Langham, Hieronimus Tragus, John Bauhin.

Samuel Fisher is the first who discovered the acid of ants, in a course of experiments for the analysis of animal substances by distillation. He even tried its action on lead and iron; and communicated his observations to J. Vray, who inserted them in the Philosophical Transactions in the year 1670. But it was the celebrated Margraaf who more particularly examined the properties of this acid in 1749. He combined it with many substances, and concluded that it greatly resembled the acetous acid. In 1777 this subject was again resumed by Messrs. Arvidsson and Oerhn; and treated in a manner which leaves little to be desired, in their dissertation published at Leipzig.

The ant which affords the greatest quantity of acid, is the large red ant which is found in dry and elevated places.

The months of June and July are most favourable for the extraction of this acid: they are then so penetrated with it, that their simple passing over blue paper is sufficient to turn it red.

Two methods may be used to obtain this acid; distillation and lixiviation.

To extract the acid by distillation, the ants are first dried by a gentle heat, and put into a retort, to which a receiver is adapted, and the fire is raised by degrees. When all the acid is come over, it is found in the receiver mixed with a small quantity of empyreumatic oil, which floats upon it, and may be separated by a funnel. Messrs. Arvidsson and Oerhn obtained, in this manner, from each pound of ants seven ounces and a half of an acid whose specific gravity, at the temperature of fifteen degrees, was to that of water as 1,0075 to 1,0000.

In the process of lixiviation, the ants are washed in cold water; and boiling water is afterwards poured over them, which is filtered when cold. More boiling water is poured over the residue, and likewise filtered when cold. By this means one pound of ants affords a pint of acid as strong as vinegar, and of a greater specific gravity. Messrs. Arvidsson and Oerhn are of opinion that this acid might be substituted instead of vinegar for domestic uses.

The acid obtained by these processes is never pure; but it may be purified by repeated distillations, which disengage the ponderous and volatile oil, and render the acid as clear as water. This acid, when rectified by this process, was found by Messrs. Arvidsson and Oerhn to have a specific gravity of 1,0011 to 1.

The acid of ants may likewise be obtained by placing linen cloths impregnated with alkali in an ant-hill. From these the formiate of pot-ash, of soda, and ammoniac, may be obtained by lixiviation. The formic acid has some resemblance to the acetous acid; but the identity of these two acids has not yet been proved. Mr. Thouvenel found more analogy between it and the phosphoric acid: but all this wants proof.

The formic acid retains water with so much force, that it cannot be entirely deprived of it by distillation. When it is

exceedingly pure, its specific gravity is to that of water as 1,0453 to 1.

It affects the nose and the eyes in a peculiar manner, which is not disagreeable. Its taste is penetrating and burning when pure, but agreeable when diluted with water.

It possesses all the characters of acids.

When boiled with the sulphuric acid, it turns black as soon as the mixture is heated. White penetrating vapours arise; and when it boils a gas is emitted, which unites difficultly with distilled water, or with lime-water. The formic acid is decomposed in this operation, for it is obtained in less quantity.

The nitric acid distilled from it, destroys it completely; a gas arises which renders lime-water turbid, and is difficultly and sparingly soluble in water.

The muriatic acid only mixes with it, but the oxygenated muriatic acid decomposes it.

Messrs. Arvidsson and Oerhn have determined the affinities of this acid with various bases in the following order: barytes, potash, soda, lime, magnesia, ammoniac, zinc, manganese, iron, lead, tin, cobalt, copper, nickel, bismuth, silver, alumine, essential oils, water.

This acid mixes perfectly with spirit of wine. It unites difficultly with the fixed oils, and with the volatile oils, by the assistance of heat. It attacks foot; assumes a fawn colour; and lets fall a brown sediment as it cools, which by distillation affords a liquor of a yellowish colour and a disagreeable smell, accompanied with elastic vapours.

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## CHAPTER XI.

### Concerning Putrefaction.

EVERY living body, when once deprived of life, performs a retrograde process, and becomes decomposed. This decomposition is called Fermentation in vegetables, and Putrefaction in animal substances. The same causes, the same agents, and the same circumstances, determine and favour the decomposition of vegetables and animals, and the



difference of the productions which are obtained, arises from the difference of the constituent parts of each.

Air is the principal agent of animal decomposition, but water and heat prodigiously facilitate its action. "Fermentatio ergo definitur quod sit corporis densioris rarefactio, particularumque aërearum interpositio: ex quo concluditur debere in aëre fieri nec nimium frigido, ne rarefactio impediatur; nec nimium calido, ne partes raribiles expellantur."—Becher, *Phys. Sub. lib. i. f. 5. p. 313. edit. Francofurti.*

An animal substance may be preserved from putrefaction by depriving it of the contact of air; and this process may be accelerated or retarded by varying or modifying the purity of the same fluid.

In those circumstances wherein we see putrefaction developed without the contact of atmospherical air, the effect is produced by the water which impregnates the animal substance, which becomes decomposed, and affords the element and the agent of putrefaction. Hence no doubt it arises that putrefaction is observed in flesh closed in a vacuum.—See Lyons, *Tertamen de Putrefactione.*

Moisture is likewise an indispensable requisite to facilitate putrefaction; and any substance may be defended from this change by completely drying it. This was performed by Villaris and Cazalet of Bordeaux, by means of stoves. The meat thus prepared was preserved for several years without having contracted any bad flavour. The sands and light porous earths preserve the bodies of men only by virtue of the property of exhausting their juices, and drying the solids. From this cause it is that entire caravans have been discovered in Arabia, consisting of men and camels perfectly preserved in the sands under which the impetuous winds have buried them. In the library of Trinity College of Cambridge, in England, a human body may be seen perfectly preserved, which was found under the sand in the island of Teneriffe. Too much humidity impedes putrefaction, according to the observation of the celebrated Becher: "Nimia quoque humiditas a putrefactione impedit, prout nimius calor; nam corpora in aqua potius gradatim consumi quam putrescere, si nova semper affluens sit, experientia docet: unde longo tempore integra interdum submersa prorsus a putrefactione immunia vidimus; adeo ut nobis aliquando speculatio occurre-

ret, tractando, tali modo cadavera anatomiae subjiciendo, quo diutius a foetore et putrefactione immunia forent." *Phys. Sub. lib. i. s. 5. cap. 1. p. 277.*

In order therefore that a body may putrefy, it is necessary that it should be impregnated with water, but not that it should be inundated. It is likewise necessary that this water should remain in the texture of the animal body, without being renewed. This condition is requisite—1. To dissolve the lymph, and to present to the air the most putrescible substance with the greatest extent of surface. 2. In order that the water may itself become decomposed, and by this means afford the putrefactive principle. Putrefaction is retarded and suspended by baking, because the flesh is dried, and by that means deprived of the humidity, which is one of the most active principles of its decomposition.

A moderate degree of heat is likewise a condition favourable to the animal decomposition. By this heat the affinity of aggregation between the parts is weakened, and consequently they assume a stronger tendency to new combinations. Hence it arises that flesh meat keeps longer during the winter than the summer, and better in cold than in hot countries. Becher has given a very intelligent sketch of the influence of temperature on animal putrefaction: "Aër calidus et humidus maxime ad putrefactionem facit . . . . . corpora frigida et sicca difficulter, imo aliqua prorsus non putrescunt, quæ ab imperitis proinde pro sanctis habita fuere; ita aër frigidus et siccus, imprimis calidus et siccus, a putrefactione quoque preservat; quod in Hispania videmus, et locis aliis calidis, sicco, calido aëre præditis, ubi corpora non putrescunt et resolvantur; nam cadavera in oriente in arena, imo apud nos arte in furnis, siccari, et sic ad finem mundi usque à putredine præservari, certum est: intensum quoque frigus a putredine præservare; unde corpora Stockholmiæ tota hyeme in patibulo suspensa sine putredine animadvertimus." *Phys. Sub. l. i. cap. i.*

Such are the causes which are capable of determining and favouring putrefaction; and hence we may perceive the best means of preventing, increasing, or modifying it at pleasure. A body will be preserved from putrefaction by depriving it of the contact of atmospherical air: for this purpose nothing more is required than to place the body in a vacuum, or to

envelop it in a covering which may defend it from the immediate action of the air; or else to envelop it in an atmosphere of some gaseous substance which does not contain vital air. We shall observe, on this subject, that the effects observed in flesh exposed in the carbonic acid, nitrogene gas, &c. are referable to a similar cause; and it appears to me that it is without sufficient proof that a conclusion has been drawn, that these same gases, internally taken, ought to be considered as antiseptic; because, in the cases we have mentioned, they act only by defending the bodies they surround from the contact of vital air, which is the principle of putrefaction. Putrefaction may be favoured by keeping bodies at a suitable temperature. A degree of heat from fifteen to twenty-five degrees diminishes the adhesion of the parts, and favours the action of the air: but if the heat be greater it volatilizes the aqueous principle, dries the solids, and retards the putrefaction. It is necessary, therefore, for the decomposition of an animal—1. That it have the contact of atmospheric air; and the purer this air is, the more speedy will be the putrefaction. 2. That it be exposed to a moderate degree of heat. 3. That its texture be impregnated with humidity.—The experiments of Pringle, Macbride, Gardane have likewise shewn us, that putrefaction may be hastened by sprinkling the animal substances with water containing a small quantity of salt; and it is to a like cause that we ought to refer several processes used in kitchens to produce this effect in food, as well as in the preparation of cheese, the curing of tobacco, the making of bread, &c.

Becher expresses himself as follows on the causes which produce putrefaction in living bodies:—"Causa putrefactionis primaria defectus spiritus vitalis balsamini est; secundaria, deinde, aër externus ambicus, qui interdum adeo putrefaciens et humidus-calidus est, ut superstitem in vivis etiam corporibus balsaminum spiritum vincat, nisi confortando augeatur; ex quo colligi potest, preservantia a putredine subtilia ignea oleosa esse debere."—This celebrated chemist concludes, from the same principles, that ligatures, copious bleedings, or any debilitation whatever, determines putrefaction. He likewise thinks that astringents oppose putrefaction only by condensing the texture of the animal parts; for he considers rarefaction or relaxation as the first effect of

putrefaction. He thinks that spirituous liquors act as anti-putrescent merely by animating and stimulating the vis vitæ. He affirms that the use of salted meats, which heat much, assisted by the moisture very common in ships and sea ports, produces the scurvy; and he observes, with reason, that the tendency and effect of putrefaction are diametrically opposite to those of generation: “nam sicut in generatione partes coagulantur et in corpus formantur, ita in putrefactione partes resolvuntur et quasi informes fiunt.”

As the phenomena of putrefaction vary according to the nature of the substances themselves, and the circumstances which accompany this operation, it follows that it must be very difficult to describe all the phenomena which it exhibits. We shall therefore endeavour to trace only those which appear to be the most constant.

Every animal substance exposed to the air at a temperature above ten degrees of Reaumur, and moistened with its own ferous humour, putrefies; and the progress of this alteration appears in the following order.

The colour first becomes pale; its consistence diminishes; its texture becomes relaxed; the peculiar smell of fresh meat disappears, and is succeeded by a faint and disagreeable smell. The colour itself at this time inclines to blue; as we see in game which begins to turn, in wounds which fall into supuration, in the various parts threatened with gangrene, and even in that putrefaction of the curd which forms cheese. Most of our food suffers the first degree of putrefaction before we use it.

After this first period the animal parts become more and more softened, the smell becomes fetid, and the colour of an obscure brown; the fibrous part easily breaks; the texture becomes dry, if the putrefaction be carried on in the open air; but the surface becomes covered with small drops of fluid, if the decomposition be made in vessels which oppose its evaporation.

To this period succeeds that which most minutely characterizes animal putrefaction. The putrid and nauseous smell which was manifested in the second degree, becomes mixed with a smell of a more penetrating kind, arising from the disengagement of ammoniacal gas: the mass becomes still less and less consistent.



The last degree of decomposition has its peculiar characters. The smell becomes faint, nauseous, and exceedingly active. This, more especially, is contagious, and transmits the seeds of infection to a great distance: it is a true ferment, which deposits itself upon certain bodies, to appear again at long intervals. Van Swieten reports, that the plague having appeared at Vienna in 1677, and having again appeared in 1713, the houses which had been infected at its first appearance were likewise infected at the second. Van Helmont asserts that a woman contracted an anthrax at the extremity of her fingers, in consequence of having touched papers impregnated with pestilential virus. Alexander Benedictus has written that pillows re-produced the contagion seven years after having been infected; that cords had remained infected for thirty years, and likewise communicated it, according to Forestus. The plague at Messina was for a long time concentrated in the warehouses where merchandize was inclosed with suspected bales. Mead has transmitted the most alarming facts concerning the durable impression of contagion.

When the putrefying substance is in its last stage, the fibrous texture is scarcely discernible, and has no longer any appearance but that of soft, disorganized and putrid mass. Bubbles are seen to escape from the surface of this matter; and the whole ends by its drying, and becoming reduced to an earthy matter, which is friable when taken between the fingers.

We do not speak of the production of worms; because it appears to be proved that they owe their origin only to the flies which endeavour to deposit their eggs upon such bodies as are best suited to support the young they contain. If flesh meat be well washed, and left to putrefy under a sieve, it will pass through all the degrees of putrefaction without the appearance of worms. It has been observed that worms are of a different species, according to the nature of the disease, and the kind of animal which putrefies. The exhalation which arises from bodies, in these different cases, attracts different species of insects, according to its nature. The opinion of those who believe in spontaneous generation, appears to me to be contrary to the experience and wisdom of nature, which cannot have committed the

re-production and number of the species to chance. The progress of nature is the same for all the classes of individuals; and since it is proved that all the known species are reproduced in one and the same manner, how can we suppose that nature departs from her plain and general laws for the small number of individuals whose generation is less known to us?

Becher had the courage to make observations, during the course of a year, upon the decomposition of a carcase in the open air; and to observe all the phenomena. The first vapour which rises, says he, is subtile and nauseous: some days after, it has a certain sour and penetrating smell. After the first weeks, the skin becomes covered with a down, and appears yellowish; greenish spots are formed in various places, which afterwards become livid and black; a thick mossy or mouldy substance then covers the greatest part of the body; the spots open, and emit a sanies.

Carcases buried in the earth present very different phenomena; the decomposition in a burying-ground is at least four times as slow. It is not perfectly ended, according to Mr. Petit, till three years after the body has been interred, at the depth of four feet; and it is slower in proportion as the body is buried at a greater depth. These facts agree with the principles which we have already established for bodies buried in the earth, and subjected to laws of decomposition very different from those which take place in bodies exposed to the open air. In this case the decomposition is favoured by the waters which filter through the earth, and dissolve and carry with them the animal juices. It is also favoured by the earth, which absorbs the juices with more or less facility. Messrs. Lemery, Geoffroy, and Hunaud have proved that argillaceous earths exert a very slow action upon bodies; but when the earths are porous and light, the bodies then dry very speedily. The several principles of bodies absorbed by the earth, or carried by the vapours, are dispersed through a great space, imbibed by the roots of vegetables, and gradually decomposed. This is what passes in burying-grounds in the open air; but it is very far from being applicable to the sepulchres which are made in churches and covered places. Here is neither water nor vegetation; and consequently no cause which can

carry away, dissolve, or change the nature of the animal fluids: and I cannot but applaud the wisdom of government, which has prohibited the burying in churches; a practice which was once a subject of horror and infection.

The accidents which have happened at the opening of graves and vaults are but too numerous, to render any apology necessary for our speaking a few words respecting the method of preventing them.

The decomposition of a body in the bowels of the earth can never be dangerous, provided it be buried at a sufficient depth, and that the grave be not opened before its entire and complete decomposition. The depth of the grave ought to be such that the external air cannot penetrate it; that the juices with which the earth is impregnated may not be conveyed to its surface; and that the exhalations, vapours, or gases, which are developed or formed by decomposition, should not be capable of forcing the earthy covering which detains them. The nature of the earth in which the grave is dug, influences all its effects. If the stratum which covers the body be argillaceous, the depth of the grave may be less, as this earth difficultly affords a passage to gas and vapour; but in general it is admitted to be necessary that bodies should be buried at the depth of five feet, to prevent all these unhappy accidents. It is likewise necessary to attend to the circumstance, that a grave ought not to be opened before the complete decomposition of the body. This decomposition, according to Mr. Petit, is not perfect until the expiration of three years, in graves of four feet depth; or four years, when they are six feet deep. This term affords many varieties, according to the nature of the earth, and the constitution of the subjects buried in it; but we may consider it as a medium. The pernicious custom which allows a single grave to families more or less numerous, ought therefore to be suppressed; for in this case the same grave may be opened before the time prescribed. These are abuses which ought to occupy the attention of government; and it is time that the vanity of individuals should be sacrificed to the public safety. It is likewise necessary to prohibit burying in vaults, and even in coffins. In the first case, the principles of the bodies are spread into the air, and infect



it; in the second, their decomposition is slower and less perfect.

If these precautions be neglected; if the dead bodies be heaped together in too confined a space; if the earth be not proper to absorb the juices, and decompose them; if the grave be opened before the entire decomposition of the body—unhappy accidents will, no doubt, be produced; and these accidents are but too common in great towns where every wise precaution is neglected. An instance of this happened when the ground of the church of St. Benoit at Paris was dug up a few years ago: a nauseous vapour was emitted, and several of the neighbours were affected by it. The earth which was taken out of this grave was unctuous, viscid, and emitted an infectious smell. Messrs. Maret and Navier have left us several similar observations.

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#### CONCERNING MINERAL WATERS.

THE name of Mineral Water is given to any water whatever which is sufficiently loaded with foreign principles to produce an effect upon the human body, different from that which is produced by the waters commonly used for drink.

Men, doubtless, were not long in attending to the differences of waters. Our ancestors appear even to have been more strictly attentive than ourselves to procure wholesome drink. It was almost always the nature of the water which determined their preference in the situation of towns, the choice of habitations, and consequently the union of citizens. The smell, the taste, and more especially the effects of waters upon the animal economy, have been thought sufficient, during a long time, to determine their nature. We may see, in the writings of Hippocrates, how much observation and genius are capable of performing in subjects of this nature. This great man, of whom it would afford but a very imperfect idea to consider him merely as the Father of Medicine, was so well acquainted with the influence of water upon the human body, that he affirms that the mere quality of their usual drink is capable of modifying and producing



a difference between men; and he recommends to young physicians to attend more particularly to the nature of the waters their patients ought to use. We see the Romans, who were frequently under the necessity of settling in parched climates, spared no exertions to procure wholesome water to their colonies. The famous aqueduct which carried the water of Uzes to Nismes, is an unequivocal proof of this; and we still possess several mineral springs at which they formed colonies, for the advantage of the baths.

It was not till near the seventeenth century that the application of chemical methods to the examination of waters was first made. We are indebted to the present revolution of chemistry for the degree of perfection to which this analysis has been carried.

The analysis of waters appears to me to be necessary, in order—

1. That we may not make use of any water for drink but such as is wholesome.

2. That we may become acquainted with those which possess medicinal virtues, and apply them to the uses to which they are suited.

3. To appropriate to the different works or manufactories that kind of water which is the best calculated for their respective purposes.

4. To correct impure waters, or such as are either impregnated with any noxious principle, or charged with any salt.

5. To imitate the known mineral waters, in all places and at all times.

The analysis of mineral waters is one of the most difficult problems of chemistry. In order to make a perfect analysis, it is necessary to be aware of all the distinctive characters of the substances which may be held in solution in any water. The operator must be acquainted with the means of separating from an almost insensible residue the different substances which compose it. He must be able to appreciate the nature and quantity of the products which are carried off by evaporation; and likewise to ascertain whether certain compounds are not formed by the operations of his analysis, while others may be decomposed.

The substances contained in waters are held either in suspension or in solution.

I. Those substances which are capable of being suspended in waters are, clay, siliceous matter in a state of division, calcareous earth, magnesia, &c.

Those which are soluble are, pure air, the carbonic acid, pure or compound alkalis, lime, magnesia, the sulphates, the muriates, the extractive matter of plants, hepatic gas, &c. The most ancient, the most general, and the most simple division of mineral waters, is that which distinguishes them into cold waters and hot or thermal waters, accordingly as their temperature is the same, or exceeds that of common water.

A division founded on the several qualities of these waters, will arrange them in four classes.

I. Acidulous or Gaseous Waters.—These are known by their penetrating taste; the facility with which they boil; the disengagement of bubbles by simple agitation, or even by mere standing; the property of reddening the tincture of turnsole; the precipitating lime-water, &c.

They are either cold or hot. The first are those of Seltz, of Chateldon, of Vals, of Perols, &c. The second are those of Vichi, of Montd'or, of Chatelguyon, &c.

II. Saline waters, properly so called.—These are characterised by their saline taste, which is modified according to the nature of the salts they contain. The salts most generally found in waters are, the muriate of magnesia, the sulphates of soda, of lime, &c. Our waters of Balaruc, of Yeuset, &c. are of this nature.

III. Sulphureous Waters. These waters have long been considered as holding sulphur in solution. Messrs. Venel and Monnet opposed this assertion. Bergmann has proved that most of these waters are merely impregnated with hepatic gas. It appears, however, that there are some which hold true liver of sulphur in solution, such as those of Bareges and of Cotteret; whereas the waters of Aix la Chapelle, Montmorency, &c. are of the nature of those mentioned by Bergmann. We may, with Mr. De Fourcroy, call the first by the name of Hepatic Waters, and the latter by the name of Hepatized Waters.

This class is known by the smell of rotten eggs which they emit.

IV. *Martial Waters.*—These have the property of exhibiting a blue colour by the solution of prussiate of lime: they have besides a very evident astringent taste. The iron is held in solution either by the carbonic or the sulphuric acid. In the first case the acid is either in excess, and the water has a penetrating subacid taste, as the waters of Buffang, Spa, Pyrmont, Pougues, &c.: or the acid is not in excess, and consequently the waters are not acidulous; such are the waters of Forges, Condé, Aumale, &c. Sometimes the iron is combined with the sulphuric acid, and the water holds in solution a true sulphate of iron. Mr. Opoix admits this salt in the waters of Provins; and those of Rougne near Alais are almost saturated with it. Mineral waters of this quality are frequently found in the vicinity of strata of pyrites. There are several near Amalou, and in the diocese of Uzes.

There are some waters which may be placed indiscriminately in several of the classes. Thus, for example, there are saline waters which may be confounded with gaseous waters, because air is constantly disengaged from them. The waters of Balaruc are of this kind.

We do not comprehend among mineral waters those which suffer gas to escape through them, without communicating any characteristic property; such as the burning spring of Dauphiny, &c.

When the nature of any water is ascertained, its analysis may be proceeded upon by the union of chemical and physical means. I call those methods physical, which are used to ascertain certain properties of water without decomposing them. These methods are, for the most part, such as may be carried into effect at the spring itself. The appearance, the smell, and the taste afford indications by no means to be neglected.

The limpidity of any water indicates its purity, or at least the accurate solution of the foreign principles it may contain; an imperfect transparency denotes that foreign substances are suspended. Good water has no smell: the smell of rotten eggs denotes liver of sulphur, or hepatic gas; a subtle and penetrating smell is proper to acidulous waters; and a fetid smell characterizes stagnant waters.

The bitterness of waters in general depends on neutral salts, Lime, and the sulphates, give them an austere taste.



It is likewise of importance to ascertain the specific gravity of the water, which may be done either by means of the areometer, or by the comparison of its weight with that of an equal volume of distilled water.

The degree of heat must likewise be taken by means of a good mercurial thermometer. Thermometers made with spirits of wine ought to be rejected; because the dilatation, after the thirty-second degree of Reaumur, is extreme, and no longer corresponds with the temperature of the water. It is interesting to calculate the time which the water requires to become cool, in comparison with distilled water raised to the same degree of temperature. Notice must likewise be taken whether any substance exhales, or is precipitated by the cooling.

The observer ought likewise to enquire whether rains, dry seasons, or other variations of the atmosphere, have any influence on the temperature or quantity of water of the spring. If these causes act upon the spring, its virtue cannot but vary exceedingly. This is the cause why certain mineral waters are more highly charged with these principles in one year than in another; and hence also it arises that certain waters produce wonderful effects in some years, though in other seasons their effects are trifling. The celebrated De Haen, who analysed for several successive years all the waters in the neighbourhood of Vienna, never found them to contain the same principles in the same proportion. It would therefore be an interesting circumstance, if, at the time of taking up or bottling of these waters, a skilful physician were to analyse them, and publish the result.

After these preliminary examinations have been made at the spring, further experiments must be made according to the methods of chemistry. These experiments ought to be performed at the spring itself: but if this cannot be done, new bottles may be filled with the water; and, after closing them very accurately, they may be carried to the laboratory of the chemist, who must proceed to examine them by re-agents, and by the method of analysis.

I. The substances contained in water are decomposed by means of re-agents; and the new combinations or precipitates which are formed, immediately point out the nature of the principles contained in the waters. The most efficacious and the only necessary re-agents are the following:



1. Tincture of turnsole becomes red by its mixture with acidulous waters.

2. Prussiate of lime, and that of ferruginous pot-ash not saturated, precipitate the iron contained in a mineral water of a blue colour.

3. The very concentrated sulphuric acid decomposes most neutral salts; and forms with their bases salts very well known, and easily distinguished.

4. The oxalic acid, or acid of sugar, disengages lime from all its combinations, and forms with it an insoluble salt.

The oxalate of ammoniac produces a more speedy effect; for, by adding a few crystals of this salt to water charged with any calcareous salt, an insoluble precipitate is instantly formed.

5. Ammoniac or volatile alkali affords a beautiful blue colour with the solutions of copper. When this alkali is very pure, it does not precipitate the calcareous salt, but decomposes the magnesian only. In order to have it in a highly caustic state, a syphon may be plunged in the mineral water, and ammoniacal gas or alkaline air passed through it. The water ought to be kept from the contact of the atmosphere, which otherwise might occasion a precipitation by virtue of its carbonic acid.

6. Lime water precipitates magnesia; and it likewise precipitates the iron from a solution of sulphate of iron.

7. The muriate of barytes detects the smallest particle of sulphuric salts, by the regeneration of ponderous spar, which is insoluble, and falls down.

8. Alcohol is a good re-agent, on account of its affinity with water.

The nitrates of silver and of mercury may likewise be employed to decompose sulphuric or muriatic salts.

II. These re-agents, indeed, point out the nature of the substances contained in any water; but they do not exhibit their accurate proportions. For this purpose we are obliged to have recourse to other means.

There are two things to be considered in the analysis of any water: 1. The volatile principles. 2. The fixed principles.

1. The volatile principles are carbonic acid gas and hepatic gas. The proportion of carbonic acid may be ascertained by various processes. The first, which has been used by

Mr. Venel, consists in half filling a bottle with the gaseous water intended to be analysed. A bladder is then to be tied upon the neck of the bottle, and the water agitated. The air which is disengaged inflates the bladder; and by that indication an estimate may be made of its quantity. This process is not accurate; because agitation is not sufficient to disengage the whole of the carbonic acid. Neither is the evaporation of the water in the pneumatological apparatus much more exact; because the water which rises with the air combines again with it, and the gaseous product consists only of a part of the gas contained in the water. The precipitation by lime-water appears to me to be the most accurate process. Lime-water is poured into a determinate quantity of the water, until it ceases to cause any precipitate. This precipitate being very accurately weighed,  $\frac{1}{3}$  parts of the whole must be deducted for the proportion in which water and earth enter into it; and the remainder is the acid contained in this carbonate of lime.

Hepatic gas may be precipitated by the very concentrated nitric acid, according to the experiments of Bergmann.

The oxygenated muriatic acid has been proposed by Scheele; and Mr. De Fourcroy has pointed out the sulphurous acid, the oxides of lead, and other re-agents, to precipitate the small quantity of sulphur held in solution in hepatic gas.

2. Evaporation is commonly used to ascertain the nature of the fixed principles contained in any mineral water. Vessels of earth or porcelain are the only kind suitable to this purpose.

The evaporation must be moderate; for strong ebullition volatilizes some substances, and decomposes others. In proportion as the evaporation proceeds, precipitates are afforded, which Mr. Boulduc proposes to take out as they are formed. The celebrated Bergmann advises evaporation to dryness, and to analyse the residue in the following manner:

1. This residue must be put into a small phial, and strongly agitated with alcohol; after which the fluid must be filtered.

2. Upon the residue pour eight times its weight of cold distilled water; agitate this, and filter the fluid, after standing several hours.

3. Lastly, the residue must be boiled for a quarter of an hour in five or six hundred parts of distilled water, which fluid must be separated by filtration.

4. The residue, which is neither soluble in water nor in alcohol, must then be moistened, and exposed for several days to the sun: by this treatment, the iron which it may contain, rusts. It must then be digested in distilled vinegar, which dissolves lime and magnesia; and this solution, evaporated to dryness, affords either an earthy salt in filaments which are not deliquescent, or a deliquescent salt; which last has magnesia for its base. The insoluble residue contains iron and clay, which are to be dissolved in the muriatic acid. The iron is first to be precipitated by the prussiate of lime; and afterwards the clay by another alkali.

The salts which the alcohol has dissolved, are the muriates of magnesia and of lime. They are easily known by decomposing them by the sulphuric acid.

With respect to the salts dissolved in the cold water, they must be slowly crystallized; and their form, and other obvious qualities, will shew what they are.

The solution by boiling water contains nothing but sulphate of lime.

When the analysis of any water has been well made, the synthesis becomes easy; and the composition or perfect imitation of mineral waters is no longer a problem insoluble to chemists. What, in fact, is a mineral water? It is rain-water, which, filtering through the mountains, becomes impregnated with the various soluble principles it meets with. Why, therefore, when once we know the nature of these principles, can it not be possible to dissolve them in common water, and to do that which nature itself does? Nature is inimitable only in its vital operations; we may imitate its effects perfectly in all other processes: we may even do better; for we can at pleasure vary the temperature and the proportions of the constituent parts. The machine of Nouth, improved by Parker, may be made use of to compose any gaseous mineral water, whether acidulous or hepatic; and nothing is more easy than to imitate such waters as contain only fixed principles.

4 X

*THE END.*





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### ERRATA.

IN some of the sheets the following inaccuracies appear in the Preliminary Discourse:—Eighth line of the first page, read *principles*, instead of *priciples*—Eleventh line, for *manufactures*, *manufacturers*—And, in the third line of the second page, for *operators*, read *operators*.



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